

PHILOSOPHICAL
CONVERSATIONS:

OR, A NEW

S Y S T E M

O F

P H Y S I C S,

By Way of DIALOGUE.

With Eighty Nine COPPER PLATES.

Written in French by Father *REGNAULT*
of the SOCIETY of JESUS.

Translated into English and illustrated with NOTES

B Y

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PHILOSOPHICAL CONVERSATIONS

BETWEEN

Aristus and Eudoxus.



CONVERSATION I.

Upon the Origin, Growth, Perpendicularity and Nutritive Juices of Plants.

Eudox.



DOES Botany, or the Knowledge of Plants, charm you, *Aristus*, as well as me? Innocence and Pleasure attend it.

Arist. I always lov'd to acknowledge in a wonderful multitude and variety of Plants the fertile Hand which has spread them over the whole Surface of the Earth, not so much

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to adorn and embellish it, as to preserve to us Life and Health. What strikes my Curiosity at present, is the Nature itself, and internal Structure of Plants, their Origin, nutritive Juices, Vegetation, Direction, Generation, Fruitfulness, Culture, singular Properties, and finally, their Maladies. I shall be charmed to know your Sentiment on this head.

Eud. A Plant is an organized Body, which is merely vegetative; that is to say, which nourishes itself inwardly, which grows and propagates Bodies of the same Species, but without a Soul capable of moving or feeling. Thus one observes in Plants, Organs fit for receiving, preparing, refining and distributing the nutritive Juices, but none which seem ordained for Motion or Sensation.

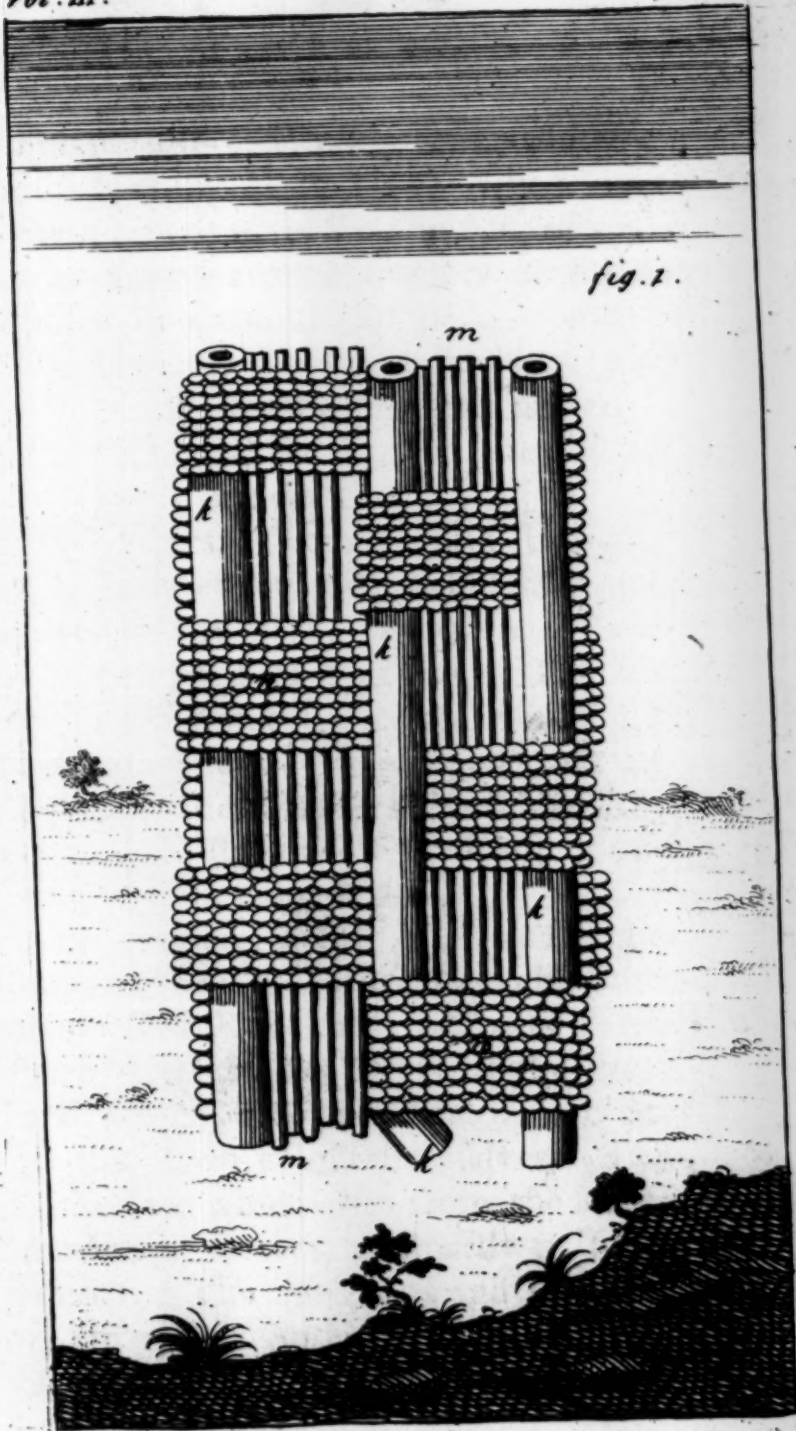
According to the Observations of that famous Botanist, *Malpighi**, the principal Organs of Plants are the ligneous Fibres (*m*), the Tracheæ (*k*), and the Utriculi (*n*), Fig. 1.

The Fibres are strait Pipes, oblong, disposed according to the Length of the Plant, and commonly interwoven in form of Threads^a. The Tracheæ are grosser Pipes, formed of a Lamina of a spiral Figure, disposed from below upward, according to the length of the Plant, sometimes united in their Course, sometimes enlarged after the Manner of Cellules, like unto the Tracheæ and Lungs of

* *Anatomes Plantarum Idea.* p. 3. *Anat.* p. 8.

^a *Anat.* p. 3.

fig. 1.



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Insects; situated almost after the same fashion^b, and whose opening is sensible, when one cuts the Stalk horizontally^c. The Microscope discovers in Wood a great number of small Pores disposed in a round and orderly manner^d. The Utriculi are small Bladders, almost oval, making several Ranges horizontal or perpendicular to the Axis of the Plant, and closed against one another^e.

From the Fibres, Tracheæ, and Utriculi horizontally interwoven with the Fibres and Tracheæ, result the Bark, Wood and Pith. The Bark is compos'd of a Pellicule, a Tissue of Fibres, Tracheæ and Utriculi^f, which are inserted into the Wood. The Wood has its Fibres, Tracheæ and Bladders; and the Pith is as it were a Collection of Vesicles, considerably like those of the Wood.

Hence the Roots, Shank or Trunk, the Buds, Branches, Leaves, Flowers, Fruit, Seed and Shoots. The Roots are the hairy Parts, whose Fibres are fitter for receiving the gross Juices, and which, for that Reason, are attached to the Earth as of themselves. The Shank is the Part which rises from the Roots to the Branches or Leaves, ordinarily in form of a Cylinder. The Burgeons and Branches are a sort of young Sprigs, or small Plants, which grow out of the Shank. The Leaves

^b Anat. p. 14.

^c Anat. Pl. Idea, p. 3.

^d Mem. de Leip-

sick, 1723. Janv. p. 36.

^e Anat. Plant. Idea. p. 2.

^f Ibid. p. 1.

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are Productions of the Fibres of the Branches or of the Shank. These Fibres being accompanied with Tracheæ and Utricoli, issue out of a Stalk, are extended at first in largeness, and then after some windings are contracted, and form the Plane or Circumference of the Leaf. The Flower is almost like the Leaf, a Contexture of Fibres, which proceed from the Bark and Wood, but finer; and according to the Texture and Arrangement of the Leaves, it is an Anemony, a Rose, a Pink. The Fruit, which one sees to grow ordinarily in the middle of the Flower, contains the Seed or Grain; and what is the Grain? It is a small Plant ready to be opened.

Arist. Then you believe, *Eudoxus*, that every Plant proceeds from a Seed, and that the Seed is a small Plant fully formed, which is only unfolded in growing.

Eud. Either every Plant proceeds from a Seed which is a small Plant already formed, and delineated in Miniature by Nature; or else there are Plants, which result from the fortuitous Concourse of certain Juices diversly agitated. Now it is inconceivable that there are Plants, which proceed from such a Concourse. For, 1. We only see Plants perfectly alike to proceed from the same Species. Could then a fortuitous Concourse be so regular as to cause so much Uniformity in an Infinity of Plants? 2. If it is a fortuitous Concourse which makes Plants, why do we
not

not daily see new ones spring up? We remark none or observe very few Species, which have been unknown till this present time. Is chance confined within so narrow Bounds? 3. The Mechanism or Structure of Plants is so compounded, and that so delicately, that all the Skill of the most enlightened and penetrating Men united in the same Design, cannot mix Juices artfully enough, so as to form the most imperfect Plant; could Chance alone then form one? Finally, whenever we perceive the smallest Part of a growing Plant, we see it wholly formed. Would Nature then affect not to shew us the Plant, but when Chance had perfected it? Every Plant therefore proceeds from a Seed; and that Seed is a small Plant, which needs only to be explicated. The Eggs of Animals and Seeds of Plants are almost the same thing. The Animal and Plant contained in Miniature, the one in its Egg, and the other in its Seed are unfolded; and this is their original and growth.

Arist. Though we have some time since discovered the Secrets which Plants made use of to conceal their Seed from our Eyes, there are some which still remain unknown to us.

Eudox. It is true: But, 1. The Number of Plants which certainly bear Seed is incomparably the greatest; and there is much more in it than Prejudice. 2. How many Plants only bear very small Seed, and such as may escape the most curious Eye?

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Arist. But after all, *Eudoxus*, if a Plant can with the Sap form a small Plant, what need is there to imagine in every Plant a Seed which is a little Plant?

Eudox. The Plant may well afford Passage to the Sap, in order to convey and distribute Nourishment. The Sap may nourish the Plant. But the Plant being only a Bundle of Fibres, Bladders, and Vessels destitute of action, and the Sap being only a fortuitous Collection of Salts, Particles of Water, and Juices received into the Plant, the Plant and Sap cannot form Roots, Trunk, Branches, Leaves, and an organized Body, which surpasses the Understanding of Men. The Plant when it propagates, only exposes to Light what the hand of the Creator has entrusted it with from the beginning of the World. And if what they report is true, that they have seen in *Silesia*, and at the Court of *Vienna*, one Shank alone bear fifteen great Ears of Barley, which rising after the manner of Pipes in an Organ, formed a very fine Plume; the Reason is, because probably fourteen Seeds being contained in a larger one, were unfolded with it.

Arist. Therefore the first Plant of every Species must have contained in its Bosom all those which have or shall grow out of it; and consequently the Author of Nature must at first have put into the least Seed an infinite number of Seeds.

Eudox.

Eudox. It is sufficient that he has put into it all those which have or shall grow out of it to the end of the World. Now is it necessary that this Number be infinite?

Arist. In vain you enclose in the smallest Seed an almost infinite Number of Plants already formed, if the Mushroom grows without Seed; but it grows without Seed. For in a word, we see it grow suddenly out of a Dunghill, and to speak more precisely from Horse-dung *. Spread Horse-dung upon the Earth, make a sort of Bed of it, water it, and after a certain time the Bed is a Nest of Mushrooms.

Eudox. If there are invisible Seeds scatter'd in divers parts, as there are invisible Eggs of Insects, and if these Seeds have need of certain Juices in order to their unfolding, it only follows from the Method of making Mushrooms grow at *Paris*, that there are some Seeds of Mushrooms diffused in divers parts, and that Horse-dung is a Species of Earth or Matter fit for causing them to spring up. Now it is probable that there are invisible Seeds diffused in divers parts, which only wait for certain Juices and Circumstances, in order to be opened. For in a word, whence proceed the black Poppies which grow out of the burnt Heaths in *Languedoc*, *Provence*, and the Islands of the *Archipelago*? Whence came that Species of Plant which covered several

* Hist. de l'Acad. 1707. p. 47.

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Acres of Earth laid waste by the Fire of *London*? Because probably new Juices and new Circumstances make the Seeds open, which were already scatter'd into divers parts. A thousand Chances may transport the small Seeds, and their smallness itself protects them from Injuries from without, preserves and renders them more delicate than the choicest Juices.

Arist. I must own, *Eudoxus*, your System is at least probable; and it ought naturally to explain the growth and vegetation of Plants.

Eudox. Let us in the first place examine the Juices, and after that we shall see the Plants grow as of themselves. The nutritive Juices of Plants are Earths, Oils, Salts, and especially Water. Different sorts of Plants afford those Principles in Distillation *; and it is well known how Water contributes to the accretion of Plants. In Winter they set over the Chimney a sort of Glass-bottles full of Water. Upon the Surface of the Water they put the Roots of Tulip, Anemomy, Jonquil, &c. The heat of the Fire is communicated to the Water. The agitated Particles of Water penetrate the Roots, and explicate them. You see the Roots descend into the Water, the Shank ascend, and Flowers grow in the height of Winter.

Would you have a Sallet formed in a little time? Of porous Earth, which they give us

* *Mariote des Plantes*, p. 23, 33, &c.

for Earth of *Egypt*, they make a Vessel with a long Neck, which they fill up with Water. Upon the external Surface of the Vessel they apply some wet Seeds of Radishes, Cresses, or other Herbs. The Pitcher transpires. The Water, which is filtred thro' its Pores, unfolds the Seed, and conveys to it Nourishment and Life; and you are surprized to see the external Surface of the Vessel, tho' very hard, produce Herbs which would grow more slowly in the best cultivated Earth. Divers Salts being diffused in the Air, and after that mixt with Rains or Vapours, penetrate the Earth as far as the Roots, and dilate the terrestrial Particles. These Particles, with the Salts and Water, are the ordinary Juices of Plants.

Arist. Nevertheless according to the famous Experiment of *Van-helmont*, Water alone seems to nourish Plants. He took two hundred pounds of Earth dried in the Oven, and having water'd it with Rain-water, he planted in it a Willow which weighed five pounds. He shut up this Earth on all sides, in a Vessel which had small holes above, for giving air to the Earth, and watering it with Rain-water from time to time. At the end of five Years the Willow weighed one hundred and sixty-five pounds; and the Earth, after it was dried again in the Oven, weighed still two hundred pounds wanting two ounces *. Is it not evi-

* Duhamel. *De corporum affectionibus*, p. 52. Journ. des Sçav. 1671. 30 Mar. p. 14.

dent that the Water alone had nourished the Plants?

Eudox. No; for in a word, 1. It is sufficiently evident that the Earth, after having been put into the Oven, was as dry the second time as the first? 2. Rain-water carries along with it terrestrial Parts, since it deposits such in the bottom of Reservoirs. 3. Dust and different Salts which the Air carries about might pass with the Air into the Vessel thro' the small holes: therefore this Experiment does not demonstrate that Water alone nourishes Plants. Would Dung render Land so fertile, if it did not furnish it with Juices?

The same Juices nourish different Plants, and produce different Fruits, according to the different Configurations which they find and receive in the Vessels of Plants. Should you graft the Bon-Chretien Pear upon a wild one, the same Juice which in this last would have produced but very small Pears, and those of a bad Taste, will produce very large ones, and of an excellent Flavour, after it has past into the Branches which the Graff shoots out. Graft upon one of those Branches a Branch of a wild Pear-tree: it only bears very small Pears, and of a bad Taste*.

Arist. This Experiment may be confirmed by another. Let eight or ten pounds of Earth be put into a Vessel: three or four thousand different Plants might find their Nourishment in this Earth, and in the Rains which water it.

* Mariote des Plantes, p. 36.

Now this quantity of Earth and Rain being united together, would not be sufficient to furnish such a Quantity of different Nourishment to so great a number of Plants. In order to this, it would be necessary that the whole Mass of this Earth and Water weighed at least four or five hundred pounds, and yet it would scarcely weigh twenty ; therefore different sorts of Plants may be nourished with the same Juices.

Eudox. These Principles being granted, one may easily comprehend the Growth and Vegetation of Plants. The small Plant has in its Seed, at least ordinarily, even before it springs up, its little Root, Stalk, Leaves and Pulp or Flesh which encompasses it, separated into two Lobes united by a Species of Thread to the Extremity of the little Root and Stalk. The nutritive Juices being push'd by the efficacy of Gravity, by their Motion proper to Liquidity, by the Action of the Spring of the Air which surrounds them, or by a certain Fermentation, insinuate themselves into the Seed, penetrate the Pulp or Flesh of the little Plant, shoot out thence into the Fibres of the Roots, and from the Stalk into the Leaves, folded up into a small Mass insensible or almost so, swell the Roots and Leaves, and make them strait, as the Air which is made to enter into a flexible and winding Tube, makes it strait ; the Action which straitens the Leaves and Roots, unfolds them by giving them opposite Directions.

This

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This Explication produces a regular Figure of a Plant ; and this is properly the Growth of the Plant.

The Growth of Plants is sensible in the French-Bean. It is a Bean composed of two Lobes, which are as it were the Body of the Bean, and of a small Plant contained within the two Lobes : The Lobes contain the Pulp or Flesh. One may discern in the Plant a small Stalk fastened to the two Lobes by two Species of Bands which are two small Channels. One Extremity of the Stalk is terminated in a Point, and that is the little Root ; the other in small Leaves folded over one another. During the Summer, soak in Water the end of the Bean farthest distant from the Bud : the Water which is filtred through the Substance of the impregnated Lobes, carries off with it some Particles of the Seed or Matter of the Lobes, passes through the two small Ducts into the Stalk, and runs into the Pipes of the Roots and Leaves. In a few days you may see the Roots unfolded, lengthned and enlarged. Afterwards the small Point is extended into Roots, and descends towards the Water. Whenever it has reached the Water, it sucks it, and transmits it to the Stalk and Leaves, which are explicated, lengthened and enlarged more and more. Thus the French-Beans grow. The same may be observed in the Seed of Gourds, Cucumbers, and Melons*. And such proba-

* Mariote des Plantes, p. 46, 47.

bly,

bly, or at least well nigh, is the growth of other Plants.

When the Burgeon is in the Earth, the Pulp or Seed impregnated with Water is at first a Source of very delicate Nourishment to it, until it hath shot out Roots capable of drawing and digesting groffer Juice. The Root is as it were the Stomach of the Plant.

Arist. But why does the Root sink into the Earth, while the Stalk rises out of it, and rises perpendicularly to the Horizon? This is a sort of Affectation. For the Root is often found upward at first, and the Stalk downward. The Root bows itself in order to descend, as one may observe in the Phaeolus, and the Stalk makes an Angle in order to ascend.

M. *Dodard* planted in a Pink-pot six Acorns, with the Point of their Burgeon upward, as perpendicular as possible: And two Months after, having taken off the Earth from them, he found that all the Roots had made an Angle to reach downward, as if they had been sensible of the Botanist's fraud*. What is it that gives to the Root and Stalk this kind of opposite Biass? This Direction strikes few Persons, because it is common; and yet it seems wonderful when one considers it nearly, and like a Philosopher.

Eud. It is probable that the Pores and Pipes of the Root are greater than those of the

* Hist. de l'Acad. 1702. p. 48.

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Stalk ; since the Root has always pass'd for the Stomach of the Plant, in which the gross Juices are digested. Wherefore when the nutritive Juices run from the Pulp into the little Plant thro' the fibrous Ducts which unite it to the Pulp, the grosser ought to pass into the Root, and the more volatile into the Stalk.

This being granted, let the little Plant be turned upside down, or not, 1. The Root ought to descend, and sink into the Earth. For the weightiest part ought to descend and sink. Its excess of Gravity gives it a Direction downward. Now the heaviest Part is the Root, since it attracts the grossest and heaviest Juice. 2. On the contrary, the Stalk ought to ascend. It must take the Direction which the volatile Juices give it ; since it only attracts the refined Juices. But these Juices being thrust upward, as Vapours by the Air, by the Matter which surrounds them, or by virtue of the Fermentation, give the Stalk which receives them a Direction upward. When the Root has reach'd the Earth, and is attach'd to it, the Juices digested and subtilized in the Root, which they have run thro' from below upward, and being protruded into the Stalk, as into so many capillary Pipes, with a vertical Direction, direct it perpendicularly to the Horizon ; after the same manner almost as the magnetic Matter, which runs thro' the Needle touched with the Loadstone from below

low upward, gives to it its own Direction. The Plant takes such a Direction with so much the more ease, because the Air surrounds it on all sides, and the Pressure parallel to the Horizon is equal on all sides, and stronger than the perpendicular; whence the Flame has always a vertical Direction, even while the Candle is placed obliquely to the Horizon.

You will ask, perhaps, why the Stalk is more perpendicular to the Horizon than the Root, which often trails only without piercing.

Arist. That is because the Stalk, as soon as it has got into the Air, meets with no Resistance to its Motion upward; on the contrary, the Root, in proportion as it descends, always encounters a great Resistance to its Motion downward into the Earth*. But thro' what does the nutritive Juice ascend from the Roots? Is it thro' the Bark, Wood or Pith?

Eud. Probably it ascends both thro' the Bark, Wood and Pith. Thro' the Bark; for hollow Trees in whose Trunks there remains no more Wood than is necessary to support the Bark, do not for all that cease to live and to produce. But cut off from the Bark one intire and whole Circle, the Plant is killed by it sooner or later. 2. Thro' the Wood; the Wood has its perpendicular Fibres; why then should they not draw Juice from the Roots? Thus green Wood is wholly impreg-

* Hist. de l'Acad. 1702. p.48.

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nated with Juices. 3. Thro' the Pith; the Pith is a sort of Sponge, fit for sucking up liquid Aliment *. One single Fact sufficiently proves that the Juices ascend thro' the Bark, Wood and Pith. In *Languedoc*, when they graff the Olive-trees in the Month of *May*, they cut the Bark horizontally three or four Fingers in Breadth, round about the Trunk or Branches; so that they uncover the Wood, or ligneous Body a little above the Graff. The Branches above the Graff at length die; no doubt because they are deprived of the nutritive Juice which ought to ascend thro' the Bark. But they do not die 'till after they have born the same year Leaves as usual, Flowers and Fruit, the double of what they used to bear †. Thro' what has the Nourishment of so many Leaves, Flowers and Fruit ascended, if not thro' the Fibres of the Wood, and Vesicles of the Pith? The Pith of the Plants, as well as the Marrow of Animals, is a Collection of small Vesicles which seem destin'd to filter and elaborate finely a Juice for the Nourishment of

* As the Pith in Quills grows dry and useleſs after the Quill is full grown, we may obſerve the ſame in the Pith of Trees, which is always ſucculent and full of Moiſture, while the Shoot is growing, by the Expansion of which the tender ductile Shoot is diſtended in every part, its Fibres being at the ſame time kept ſupple by this Moiſture; but when each Year's Shoot is full grown, then the Pith gradually dries up, and continues for the future dry and kickſey, its Veſicles being ever after empty; Nature always carefully providing for the ſucceeding Year's Growth, by preſerving a tender ductile part in the Bud replete with ſucculent Pith. *Hale's vegetable Staticks.*

† Hiſt. de l'Acad. 1709. p. 51.

Flowers and Fruits. Hence according to the Observations of M. *Magnòl*, Plants which have plenty of Pith, as the Rose-bush and Lilach, have also very many Flowers and Seeds.

Arist. This Fact brings to my mind an Elm in the *Tuilleries*, which in the beginning of Spring, tho' it was wholly stript of its Bark from the Root to the Branches, nevertheless shot out Sap into all its Parts, and preserved its Leaves during the whole Summer, but with less vigour than the others^s.

Eudox. The Force which makes the Sap ascend, makes the Branches spring out of the Trunk. The Branches are properly small Plants, which only spring out of the principal Plant, and whose Roots remain attach'd to the Trunk. The principal Plant is a Composition of almost an infinite Number of small similar Plants. Hence if one enclose the Stalk with Earth, it shoots out Roots from all Parts^h. And a Tree that has been lopped, in a short time appears adorned with small Branches. A Branch of a Fig-tree set in the Earth shoots forth Roots, and in a short time becomes an intire Plant.

Arist. But how does one Part become the intire Whole?

Eud. Since we cannot conceive that an organized Part is formed a-new, the Branch contains in itself small Roots, which could

^s Hist. de l'Acad. 1708. p. 50.

^h Mem. de l'Acad. 1701. p. 239.

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not be unfolded unless it were separated from the Tree, and put into the Earth. The Contact of the Earth, and the Nourishment which they immediately receive from it, determine them to spread and appear. And one sees a Whole issue out of a Part.

Arist. At least the Branches, not being perpendicular to the Horizon, ought to be carried downward by their Weight.

Eudox. Their Weight gives them a perpendicular Direction downward. The nutritive Juices, which impel them, or which they receive, have and give to them a stronger Direction upward; and yielding chiefly to the strongest, they ordinarily take an oblique Direction, which approaches more to the perpendicular upward, than to the perpendicular downward.

The Branches at last with their Juices terminate in Leaves. But if the Leaves draw Juice from the Roots by the Branches and the Stalk, they likewise receive some immediately from Rain, Dew or Vapours, with which the Air is always charged; and this last Juice descends as far as the Roots. In short, 1. The Leaves, as well as Stalks, have generally small Points or Threads, which appear like so many small Tubes for sucking up the Vapours and Dew. 2. Cut off a small Branch of a Tree, or of some Herb, as Parsley; soak only the End of its Leaves in Water; the little Branch is preserved green three or four days,
even

even in Summer; if it is Balm, a Species of odoriferous Herb, the little Branch is preserved more than fifteen days, as green as that of the Garden, and grows a little; whereas it would wither and dry up in a short time, if it did not touch the Waterⁱ. Therefore it is certain that the nutritive Juice enters into the Plants, both thro' the Roots and Leaves.

Arist. But do you believe, *Eudoxus*, that the Sap, in order to its being elaborated more finely, circulates in Plants, as the Blood in Animals?

Eudox. If the same Sap ascends and descends, or descends and ascends, it circulates. But 1. The same Sap ascends and descends; for when the Stalks of two Yoke-elms join their Barks together in one place, so that the Juice of the one passes into the other, if you should saw the Stalk of the one in the Month of *February*, two Foot below the joining of the Stalks, the lateral Branches, which are below the Union of the Barks, send forth small Shoots and Leaves in the Spring, as well as those which are above, and as if they received Nourishment from the Roots of their own Stalk^k. Therefore they must receive by the conjunction of the Stalks a Juice, which descends from the Branches toward the Roots, after having ascended from the Roots toward the Branches.

ⁱ Mariote des Plantes, p. 82.

^k Mariote, p. 85, 86.

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Accordingly should one meet with a Tree supported by great Roots, one of which is uncovered about a foot and an half; let it be cut four Fingers from the Earth, it will perish, unless some Juice comes to it which descends towards the Roots; after having ascended toward the Branches; since it has no more communication with the Earth. Nevertheless the year following it sends forth both Branches and Leaves¹. Therefore the same Sap ascends and descends.

2. The same Sap descends and ascends. *M. Perrault* having pluck'd up many Plants similar and intire with their Roots; took one of them, whose Trunk was divided into two Branches, and plunged it into Water only by the extremity of one of them. This Plant continued fresh, while the other were wholly dried up; and the Branch, which was not wet, sent forth new Leaves.

Consequently the Sap circulates in Plants; and this is the Opinion of *M. Perrault*, *M. Mariote*, and *M. Malpighi*, Philosophers of great Knowledge and happy Invention.

Arist. In short, Plants have ascending and descending Ducts, which are different from the first. And the first are designed for conveying from below upward, a more spirituous and subtile Liquor; and the other for conveying from above downward a more aqueous and grosser Liquor. For, take a piece of a

¹ Hist. de l'Acad. 1709. p. 48.

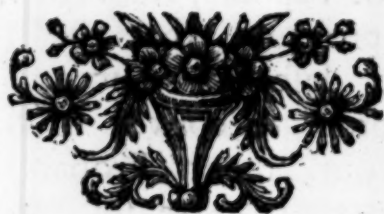
Small Elm, without Knots, about three Inches long, and upon each end put a Funnel of Wax; after that, cut the Branch in two, and pour Water into the Funnels. The Water passes into the piece of Wood, whose Funnel is at the end which was next to the Branches, before they were cut; and consequently passes from the Branches towards the Roots; but without passing into the piece of Wood, whose Funnel is at the other end, and consequently without flowing from the Roots toward the Branches. On the contrary, Spirit of Wine is readily distill'd thro' the piece thro' which the Water cannot be filtered. Now the Liquor, which goes from the Roots to nourish the Stalk, Branches and Leaves, ought apparently to have in ascending more spirituous parts for nourishing them. But after it has deposited its spirituous Particles in divers parts, it ought only to bring back from the extremities its more gross Particles, mixt with the Waters of Vapours, Rain and Dew. Therefore it is probable, that the same Liquor ascends and descends, descends and ascends again, in order to convey to the Plants an agreeable Nourishment. Probably the ligneous Fibres convey the more spirituous Juices toward the Branches; the Utricles bring back the Juices toward the Roots, which are not yet sufficiently digested; and the Tracheæ furnish Air, which facilitates the Circulation of the Juices.

22 *Of the Origin, Growth, &c.*

Eud. The Circulation of the Juices at length makes the Flowers and Fruit open. The Action of the Juices shoots out the Flowers and Fruit from the Branch, and nourishes them by making the most elaborate and finest Juices flow into their Fibres.

Arist. Is the Use of Flowers very certain?

Eud. Flowers are ordained to give for a short time a delicate Nourishment to growing Fruit, for the Production of the Plant; since the growing Fruit perishes, at least the best part of it, when the Assistance of the Flowers happens to fail. But a particular Conversation upon the Generation, Culture, and Fruitfulness of Plants will make us better understand the Use of the Flowers.





CONVERSATION II.

*Upon the Generation, Fruitfulness,
and Culture of Plants.*

Eud.  ANY look for nothing more in Flowers than to gratify their Sight and their Smell. The Virtuoso dwells upon the Smell, Structure and Beauty of the Leaves, and upon the lively Brightness and Variety of their Colours. The Philosopher finds in Flowers qualities more noble, and more worthy to be observed. You know, *Aristus*, that the Fruit encloses the Seed, and that the Seed contains a small Plant already formed by the hands of Nature for perpetuating the Species. But will you believe that the Flowers are equally necessary for the Production of the Fruit, and for putting the small Plant into a state of budding?

Arist. This is a sort of Paradox, which deserves some Illustration. Explain your self upon this Head without any fear of being interrupted. I shall find too much pleasure in hearing you.

Eudox. Flowers, at least the greatest part, have their Leaves, Calix, Stile, Stamina, and their Summits. The Calix serves to enclose the parts of the Flower. The Leaves of Flowers are parts extended and situated round about the Seed. The Pistillum is a Species of Tube which rises from the bottom and middle of the Leaves. The Stamina are Threads which arise from the bottom of the Flower, round about the Pistillum, and are terminated by extremities of a different Structure, which are called the Summits*. The Tulip, for example, is composed of six Leaves, *Fig. 2.* From the bottom and middle of those Leaves arises a small hollow Stalk (*a*); this is the Pistillum. Round this Pistillum some Threads are disposed, very fine, which also grow up out of the bottom of the Flower; these are the Stamina (*b*). The Stamina end in Extremities bigger than the rest; and these are the Summits (*c*). The Calix is the first covering of the essential parts of the Flower. The Leaves defend them from the Injury of the Air. The Pistillum contains in it the Embryo's of the Seed, whereof it is as it were the Ovarium. The Summits of the Stamina are Capsules or Vesicles, which in their maturity open and send forth a Dust of different Configuration, according to the difference of Plants. This being granted, if it is the Dust of the Summits which makes Plants fruit-

* *Mem. de l'Acad. 1711. p. 210.*



fig. 2.

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ful, the Flowers are the principal Organ of Generation in Plants. Now, it is this Dust which makes Plants fruitful; for according to the Observations of M. *Geofroy*, 1. The known Plants, at least almost all the terrestrial Plants, have their Summits and Dust either upon the same foot or upon separate ones*. 2. The Summits and Pistillum, if joined in the same Flower with the same Foot, are always situated in such sort, that the extremity of the Pistillum necessarily receives the Powder of the Summits, when they are faded. In bending Flowers, as in the Crown-Imperial, the Pistillum is lengthened out much beyond the Stamina, so that the Dust necessarily covers the extremity of the Pistillum, when it falls. Finally, without the aid of this Dust the Embryo's of the Seeds prove abortive^a. Thus when Fruit-trees are in blossom, if there comes a white Frost with a Sun-shine, which dries up the Pistillum, and makes it incapable of receiving the Dust from the Summits, the Gardener's hopes are frustrated. If the Corn blossoms, and the Mildew or Rain corrupt or make the Summits fall, the Cells of the Seed are empty, or the Seed unfruitful. If an excessive Rain happen during the blossoming of the Vine, the Summits and Dust are carried off by the Weight and Action of the Water; the Grapes drop off. And in Plants whose Stamina spring

^a Mem. de l'Acad. 1711. p. 223.

up on the same Pedicle, if one cut those Stamina before the Summits are open, the Fruits do not come to maturity; or if they ripen, they are barren ^b. Therefore the Flowers are the principal Organ of Generation in Plants.

Arist. But how shall we accommodate this Hypothesis to those Plants, of which one Species bears Flowers without Fruit, and the other Fruit without Flowers; and of which some bear Stamina and Summits upon a different Pedicle from those which bear the Fruit?

Eud. The Dust of the one goes to impregnate the Seed of the other, separated and often very distant. Hence the Male and Female Plants. The Plants which only bear Flowers, and make the other fruitful, are called Male Plants. Those, which only bear Fruit, and are made fruitful by the first, are called Female Plants. Has the Female Palm no Male in its neighbourhood, at least for some distance? It bears no Fruit. If it bears any, they do not ripen, they are of a bad Taste, without Kernel ^c and without Burgeon; therefore they take care to plant a Male Palm near the Female, or to cut some Branches of the Male Palm charged with some faded Summits, and fasten them over the Branches of the Female ones. And then the Female

^b Mem. de l'Acad. 1711. p. 225.

^c Mem. de l'Acad. 1711. p. 226.

Palm bears teeming Fruit in abundance, and of a good Taste.

Arist. But what is the Vehicle of the Dust of one Pedicle to the Fruit of another?

Eud. The agitation of the Air or the Wind. A remarkable Fact is a sufficient good Proof of it. If we credit a Poet upon this head, two Palms have been observed distant from one another more than fifteen Leagues, the Male at *Brindes*, the Female in the Wood of *Ottrante*. The Female Palm of *Ottrante* was many years without Fruit: But whenever it had lifted up its Head above the other Trees of the Forest, and could see the Male at *Brindes*, it became fruitful, and begun to bear Fruit of a good Taste and in plenty^d; probably because then it begun to receive the Farina, which the Wind brought from the Stamina of the Male Palm, upon the Embryo's of its Fruit, over the other Trees. Is it not natural to think that the Wind and Dust of the Stamina had more share in this marvellous Event, celebrated in Poetry, than the Love and Sympathy of Trees of different Sexes?

Arist. Therefore, *Eudoxus*, the Powder of the Stamina, which is sulphurous, and compos'd of subtile and penetrating Particles, as the Scent sufficiently shews, falling upon the Pistillum, which contains the Fruit, must be dissolved; must penetrate the Substance of the Pistillum and Fruit, and at length cause a Fer-

^d Mem. del'Acad. 1711. p. 228.

28 *Of the Generation, &c.*

mentation capable of making the little Plant contained in the Seed unfold and bud.

Eud. This seems to be the Principle both of the Generation and Fruitfulness of Plants. Fruitfulness is still a Wonder sufficiently exposed to our sight, without having been hardly ever observed: which yet did not escape the Observation of M. *Dodart*. He chose an Elm of six Inches diameter, twenty Inches high to the shooting out of the Branches, and which might be twelve years old. He caused a Branch of it eight Foot long to be pulled down. Upon this Branch were found 16450 Seeds ^e.

This being granted; as there are no new Seeds formed ^f, a Tree of this kind really contains at least fifteen Billions eight hundred and forty Millions of Seeds, very distinct and separate from one another; without counting those, which each Seed may contain; and consequently wherewith it may produce itself a-new so many times.

Wonderful Source! For in a word, an Elm of six Inches diameter, has at least ten Branches of eight Feet; and these contain 164500 Seeds. The other Branches taken together may bear as many Seeds, and so there will be in all the Branches 329000 Seeds.

The Age of twelve Years is not that of the common Fertility of the Elm: we may allow

^e Hist. de l'Acad. 1700. p. 65. Memoire 1700. p. 155.

^f 1 Conversation. T. 3. p. 6.

it 330000 Seeds for its Fertility, taking one year with another. This Elm may for an hundred years bear 330000 Seeds every Year. The 330000 Seeds must be multiplied by the hundred years of fecundity; and that will be 33000000 of Seed. Lop the Elm, the Extremity of the Trunk that is lopt will send forth as many Shoots or Branches as it had, in the space of about six Lines in height. In whatever part one lop it, it will always shoot forth equally, as appears from Dwarf-trees, which are cut almost level with the ground. Consequently if you divide the Trunk from the ground to the growth of the Branches, into circular Rings six Lines high, every Ring ought to contain as many invisible Branches, and in those Branches as many Seeds, as the Branches which appear: wherefore this Elm contains as many times 33000000 of Seed, as six Lines of height are contained in the height of twenty Foot. Therefore there are in the Elm 15840000000 of Seed. What do I say? Each Seed contained in the Elm, does it self contain an Elm, which contains the same number of Seeds. Therefore the Elm contains 15840000000 of times fifteen thousand Billions 840000000 of Seeds. Every Seed of these fifteen thousand Billions contains as many, and so forth.

Arist. I must acknowledge, *Eudoxus*, Reason conducts the Imagination thus far in this immense Calculation. But at last, both Reason

30 *Of the Generation, &c.*

son and Imagination find themselves as it were lost and swallowed up in an Abyſs.

Eud. After all, is it ſurprizing that Power and Wiſdom without bounds ſhould have every where ſpread traces of Infinity? Certainly we ſee them in the fertility of Plants. But why muſt a great number of Trees be grafted in order to produce good Fruit?

Ariſt. I ſhall ſoon ſee the Reason of that in your opinion concerning Grafts.

Eud. To graff or to inoculate a Tree, is to inferſt in it a Graft or Shoot of another Tree, ſo that the Graft and the Tree grafted may become one and the ſame Plant. They inoculate after ſeveral methods. To inoculate by cleft, is to cleave the Tree which one inoculates, and to place the Graft in the Cleft. To inoculate in the Bark, is to put the Graft between the Bark and the Wood. To graff by Scutcheon, is to remove from off a Tree a Scutcheon or Shoot, with a great part of the Bark, out of which it riſes, and to apply it upon another. They make a ſort of Covering to the Wounds of grafted Trees, not only to hinder the action of the Air upon the Wounds, leſt it ſhould dry up the Fibres, and render them incapable of transmitting or receiving the nutritive Juice, but that the nutritive Juice aſcending abundantly in the Spring, may be ſhut up from a poſſibility of diſſipating, and conſtrained to ſwell the Veſſels of the Graft, which it finds open. The Juice, by vir-

due of its passing from the Trunk into the Graft, unites them at last in one and the same Plant.

Arist. But why does the Graft bear the same Fruit, and Fruit of the same Taste, as the Tree from which it proceeds?

Eud. Because the Fruit is produced from the Graft, which received its Seeds from the Tree out of which it was taken; and because the Juices, which flow thro' the Fibres of the Graft, do therein take a Configuration conformable to the Graft; and to the Tree which produced it.

Arist. The Fruit of the Graft is better.

Eud. The Juice, which nourishes it, is better prepared; because it is fermented and subtilized, not only in the Trunk, but in the Graft, whose Texture is different, more compact, or more proper for purifying the Juice.

Arist. Finally, grafted Trees are generally more fertile than others.

Eud. Because they commonly make choice, for grafting, of Sets, whose Roots being more extended, receive more Juice. Besides the Juice which is filtred thro' the Grafts, being more pure, is also more proper to nourish and bring forth the Fruit.

Culture contributes to the Fecundity of Plants proportionally as it prepares and distributes the nutritive Juices. When you would have the Scutcheons cover the Wall the same Year, and leave no Vacuity in the Espalier, you must pull off the Blossoms, that so the Sap
not

not being employed in nourishing either the Blossoms or Fruit, may afford the more to the Branches. If the Branch of the Scutcheon has shot out to the length of eight or nine Inches, it is good to nip it at the end, because the Sap being stopt by the extremity which is nipt, dried up, and incapable of accretion, will cause a great number of small Branches to spring out, which will bear plenty of Fruit the following Year *.

Are you willing, *Aristus*, that on the first Opportunity we talk of several curious Plants, both marine and terrestrial; of Coral for example, Mushrooms, Gin-seng, the Coffee-tree and sensitive Plant?

Arist. If you will explain yourself upon the Coral, Mushrooms, and Gin-seng, I will reserve the Coffee and sensitive Plant for myself.

* Mem. del'Acad. 1716. p. 199.





CONVERSATION III.

Upon the Plants of the Sea, Coral, Mushrooms, and Ginseng.

Eud.  O U would have me then, *Aristus*, explain myself upon the Plants of the Sea, and particularly upon Coral, Mushrooms and Ginseng.

As the Sea has its Animals different from the Land, it has also its Plants different from those which the Land produces. Amongst the marine Plants, some have Leaves, and others none. The greatest part have no apparent Roots, and come up on hard Bodies, such as Rocks and Shells to which they are attach'd by a smooth and polish'd Base. Those Plants without Roots, may pass for Roots in their whole Substance; that is to say, organized in such a manner, as to attract Aliment on all sides by an infinity of Pores. In short, marine Plants are on all sides surrounded with the Water of the Sea, which nourishes them; and so far as *M. Marsilli* could observe with a

34 *Of the Plants of the Sea,*

Microscope *, they are only a collection of small Glands which filter the Sea-water, and separate from it the lacteous and glutinous Juices, in order to nourish themselves therewith.

There are stony Plants in the Sea, as the Corals. Coral ordinarily grows attach'd to the upper part of a Cavern, with the Branches downward, contrariwise to Land Plants. It is equally hard in the Water and out of it. What proves the Coral to have been a Liquid in its first formation, is, that sometimes it covers the inside of a Shell. The Surface of the Coral being stript of its Bark, is all furrow'd with Channels which reach the extremity of the Branches. The extremity of the Branches of Coral is inflated, formed round, and contains some Lodges full of a sharp, caustic and viscons Milk. This Milk running out of its Lodges, and falling into the Water, without being mixt with it, is attach'd to Bodies which it encounters; and probably fastens to them a very minute Plant, which being open'd, discovers at first a reddish Point, as M. *Tournefort* conjectures, and then a Coral Plant*. The Coral has its Flowers; a Discovery which we owe to Count *Marfilli*. They are white. Every one has its Pedicle and eight Perals. These Flowers spring out of all the small Tubes of the Bark. Draw the Plant out of Water; the Flowers enter again into the small

* Hist. de l'Acad. 1710. p. 72.

* Hist. de l'Acad. 1700. p. 35.

Conv. III. *Coral, Mushrooms, &c.* 35

Tubes. If you put it again into Water, you see it blossom a-new in less than an Hour. Sometimes for the space of twelve days it is contracted and blown as often as one pleases ^b. After which, its Flower falls to the bottom of the Water in the form of a small yellow Ball.

2. The Mushroom is one of those Land-Plants that are most curious in the eyes of Philosophers. The Method by which they make it grow up at *Paris* is singular enough, as we have already observed. In order to have of it all the year, they make two sorts of Beds, the one in Gardens, and the other in the Fields. Those afford Mushrooms from *All-saints* to the end of *April*; and these from the Month of *May* to the earliest Frosts^c. These Beds are made with Horse-dung. To make those in the Gardens, they heap up the Dung in the Month of *June*. In the Month of *August* they spread it out to the height of a Foot upon the places where they have a mind to make the Beds. They water the Dung for five or six days, according to the drought of Summer. After having wetted it, they turn it over with a Fork that so it may imbibe the Water. After this preparation, they make the Beds with three Lays. These Lays are prepared fifteen days, or three Weeks, one after another. The first Lay has two Foot and an half in

^b Hist. de l'Acad. 1710. p. 76.

^c Mem. de l'Acad. 1707. p. 58.

36 *Of the Plants of the Sea,*

breadth, and one Foot and a half in height. And if the Season is too dry, they wet this Lay every day.

Toward the middle of *August*, with the same Dung which they used for the first Lay, they raise up the second with a sharp Ridge, to the height of one Foot above the first. They wet it. They trim the height again handsomely, and this reparation they call the third Lay.

The Paths which are between the Beds, are five or six Foot broad. They cover these Beds with Mould, which has been used for Beds of Melons. They lay it about the thickness of an Inch. To make Mushrooms come up speedily and in abundance upon these Beds, they sink into them a Foot deep, and three Foot distant from one another, upon the same Line, pieces of a Dunghill as large as one's Fist, prepared and thrown up together in the Month of *February*. When they have ranged these Parcels of Dung in the Bed, they cover it with Mould. Over the Mould they place some fresh Litter just taken from under the Horses. After this they touch the Beds but every eight Days. Are they cool'd? They must be covered with fresh Litter. If it freezes, to divert the Frost they immediately cover the Mould with dry Dung, and over this Dung they put wet Dung. If the Beds smoak too much, they leave only a half covering of Dung. When the Mushrooms begin to spring up, the
Dung

Conv. III. *Coral, Mushrooms, &c.* 37

Dung grows white ; one sees it bestrewed with small white Threads, fine, ramous, and twisted about the Straw, whereof they are formed. The Dung no longer retains its smell, but diffuses the Scent of Mushrooms. Those white Threads are probably the Burgeons of the Mushrooms. The extremity of those Threads is formed round, and becomes a Button, which encreases by little and little. *M. Marchand*, a skilful Botanist, presented the Academy of Sciences with a view of the first formation of Mushrooms in mouldy Horse-dung^d. They begin to gather Mushrooms in *October*, and this gathering is generally made every third or fourth day.

They raise the Beds in the Field in the Months of *November* and *December* with fresh Earth ; that is, such as has not produced Mushrooms for a long time. These Beds commonly afford Mushrooms from the Month of *May* to the earliest Frosts. The lower part of these Mushrooms is a Pedicle bearded in that part which is sunk into the Earth, and bearing on the other end a sort of round Head in the form of a Cap. The upper part of it is spread out into Rays, and the Laminae which pass from the Center to the Circumference, are as it were the Leaves of the Mushrooms. I don't know whether you will believe what they tell us, that in the Confines of *Hungary* and *Croatia* there grow Mushrooms

^d Hist. de l'Acad. 1678. p. 169.

38 *Of the Plants of the Sea,*

of such a prodigious size, that one alone would load a Waggon *.

3. The Ginseng is a precious Plant, very rare, and much sought after, for the sake of the Root. The Root of it is commonly forked into two pretty large Branches, like the two Thighs of a Man. And thence comes the Name of Ginseng, which in *Chinese* signifies *the Thighs of a Man*, or something resembling them †.

The Ginseng has excellent Vertues: It revives the natural heat, gives motion to a feeble Pulse, purifies the Blood, and fortifies the Stomach. Thus according to the Expression of the *Chinese*, it is the spirituous Simple, the pure Spirit of the Earth, a Receipt for Immortality. Father *Jartoux*, a Jesuit, a Missionary to *China*, saw a body of ten thousand *Tartars* gathering Ginseng in *Tartary* that is subject to the Emperor of *China*. This Monarch buys it at the weight of fine Silver, and sells it again four times dearer in his own Dominions, where it is sold only in his Name. Father *Joseph Lafiteau*, the Jesuit, found it in *Canada*. This wonderful Plant is scarcely found any where else, but in the Forests of *Canada*, and those of *Tartary*. The missionary Jesuits have in their Travels met with two choice Plants, the Ginseng and Quinquina or Jesuit's Bark.

* Journ. des Scav. 1678. p. 176. 2 May.

† Hist. de l'Acad. 1718. p. 41.

Conv. III. *Mushrooms, Ginseng, &c.* 39

You are now, *Aristus*, to describe me the Coffee-tree, and teach me after what manner, and upon what principles a Philosopher extracts an excellent Liquor from the Fruit of this Tree.

Arist. In the Royal Garden of Plants a Tree may be seen of this Species, between five and six foot high, and an inch thick. The Branches of this Tree spring out from space to space, the length of its Trunk, continually opposite by two and two, and ranged in such sort that one Pair crosses another. In all Seasons they have their Leaves entire; sharp at the two ends, opposite by two and two, pretty like those of the Laurel, but ordinarily larger and sharper; of a comely green, gay and bright upward, of a pale green downward, of a yellow green in their growth, waved in the edges; having two inches or more in breadth, above four or five in length, and their Stalks very short.

From the wing of the Leaves, Flowers spring up of a sweet and agreeable Odour, each of them supported by a very short Pedicle; all over white; with white Stamina and yellow Summits, disposed round about a forked Stile, which surmounts the Embryo or young Fruit, placed in the bottom of a green Calix.

The young Fruit is green, clear at first, then reddish; after that of a fine red, and lastly, obscure when ripe; of the Bigness and Figure almost of a hard Cherry. The Pulp

40 *Of the Plants of the Sea,*

which encloses it has two Shells, minute and oval. Each contains a Seed oval and vaulted on one side, and flat, hollow or furrowed on the opposite side, where the two are joined together. They call *Coffee in the Shell*, the whole Fruit being dried; and *cleansed Coffee*, the Seeds stript of their Covers. The Coffee of the Royal Garden has the same Taste as that which is brought from *Arabia*.*

The Coffee-tree grows in *Arabia* toward the Road of *Moka*, to the height of 40 foot; while the Diameter of its Trunk does not exceed four or five inches. It is seen almost continually in blossom, and bears Fruit two or three times a year.

The Seed of the Coffee-tree ought to be put into the Earth quite fresh, if possible, as M. *Jussieu* has observed in the Royal Garden. This Plant has multiplied. It has spread into divers Countries. It has reached as far as into *America*. *Caienne* has its Coffee.

The use of Coffee is common in *Turkey*, *Persia*, *Armenia* and *Europe*. For roasting it, Vessels of varnished Earth are more proper than those of Iron or Brass; because the last may communicate to it the impression of Iron or Brass. A Sign of its being roasted to a due degree, is its Colour inclining to violet. Would you make the Infusion or Liquor of it as agreeable and profitable as possible, you must powder it the very moment you have a

* Mem. de l'Acad. 1713. p. 294. mind

Conv. III. *Mushrooms, Ginseng, &c.* 41

mind to infuse it; and you must infuse it in boiling Water, because it then loses less of its volatile Salts that are piquant and capable of pleasing the Taste, and agitating the Blood. Those Salts are probably the Principles of its special Virtues.

Eudox. The principal Virtues of Coffee are, as I think, without speaking of the Taste, to facilitate Digestion, cure the Hypo, dissipate Humours, prevent Drowsiness, keep one awake, render the Ideas distinct, and to confirm the Memory. One may give credit to Orators on this head.

Arist. Coffee contains volatile Principles, both saline and sulphurous, if one judge of them by the oily matter which appears upon the surface when one roasts it, and by the Odour which it diffuses. These Principles are probably the source of the Virtues which you attribute to it. The Salts ought to incide the Viscerals, and by that means facilitate Digestion. The mixture of the Salts and Sulphurs in the Blood cause Fermentations, which open the Vessels, and cause obstructed Humours to flow. Hence the Hypo and Drowsiness are dissipated. Finally, the spirituous Particles, which arise as far as the Brain, agitate it, and agitate the Traces to which the Ideas are attach'd. This Agitation incessantly presents new Ideas to the Mind; and hence proceed waking, and distinct Ideas.

The

42 *Of the Plants of the Sea,*

The Sensitive Plant of the Royal Garden has something in it that touches me still more. Would you not say that this Plant has some Sensation, and that it deserves the Name which it bears? Whenever the Finger seems to be upon the point of touching it, the Leaves contract themselves, fall down upon their Branches, and the Branches upon the Stalk. The Plant is contracted, and in vain should you attempt to extend it, or restore it to its former figure by touching it; it would sooner suffer it self to be torn to pieces.

Eudox. Is it a sort of Bashfulness then which contracts it, and keeps it so obstinately contracted?

Arist. When one approaches it with the Hand, there issue Spirits out of the Finger by Transpiration. These Spirits penetrate the Fibres of the Plant, interrupt the Course of the Juices, and stop their Circulation. The Circulation of the Juices being stopt, there are Fibres which swell and shrink. This shrinking contracts the Plant. And this seems to be the Principle of the Sensibility of the Sensitive Plant.

Eudox. The Sensitive Plant has something extraordinary in it; but according to the Journals of the Learned, *Germany* is fertile in Plants much more curiousⁿ. They have gathered there Morilles which they could scarcely cut by reason of the Particles of Silver which they

ⁿ Journ. des Sçav. 17 May 1683. p. 143.

contained.

contained. They have seen a Rod of Silver growing in a Wood, and a silver Wand issue out of a Rock. Gold has been found in the Pith and Veins of Trees. What do I say? They have seen Gold it self rise out of the Earth in small Threads, and twist it self round about the Vine; in a Field of Oats they reaped Ears of Metal, wherewith they presented the Emperor *Rodolphus*.

Arist. These Phenomena, I think, are too singular to be probable. Could the Juices destined by Nature to form the most precious Metals, have been thrust by the Fermentations of the Earth into the Tubes of Plants, and have taken the figure of them before they were hardened; or could the metalline Particles, already formed, ascend into the Plants, and ordinary Juices, in order to assume therein different figures of Plants, by uniting themselves to one another in Tubes differently turned? The Plants have probably Particles of Iron, since with a Loadstone they find Particles of Iron in the Ashes of Plants; and it is affirmed that a Brook in *Hungary*, changes the Leaves of an Oak into Leaves of Copper, which continually preserve their former figure of the Leaves of an Oak¹; because the metalline Particles, which penetrate the Leaves of Oak, are united to them, and disposed according to the texture which they find in them.

¹ Journ. des Sçav. 6 Fev. 1679. p. 36.

44 *Of the Plants of the Sea,*

Eudox. The Idea of Leaves brings to my mind both the *Enseté* and *Tallipot*. “ I saw in “ *Abissiny*, says a Missionary^k, a Tree which “ they call *Enseté*. Its Leaves are so large, “ that two of them are sufficient to cover “ a Man both behind and before. They hang “ Rooms with them, they make use of them “ for Carpets, for Napkins, and Towels, “ and the green of them is very fine. They “ grind the Branches or thick Ribs of the “ Leaves, and reduce them into a very fine “ and white Meal, which being soak’d and “ boil’d with Milk, is delicious Food; the “ Trunk and Roots are more nourishing “ than the Branches. They cut the Trunk “ into pieces like Turnips, and boil them with “ Meat. Oftentimes the wealthy themselves “ eat them by way of Regale. The *Abissines* “ say, that when one cuts this Tree, it utters “ sighs; and when they would say that they “ are going to cut an *Enseté*, they say we “ are going to kill an *Enseté*. This Tree “ bears on its top a long Pod, which contains “ five or six hundred Figs.”

The *Tallipot*^l is a Tree which grows in the Island of *Ceilon*. Is is of the height and thickness of a Mast of a Ship. The Leaves of this Tree have something in them still more astonishing than that of the *Enseté*. They say that the Leaves of the *Tallipot* are so

^k Father Lobo J. Hist. Relat. of *Abissiny*, p. 113.

^l Mem. de Trev. May 1703, p. 860.

large,

Conv. III. *the Tallipot, Tea, &c.* 45

large, that one of them alone may serve to cover fifteen or twenty Persons together.

Arist. On the contrary, the Leaves of the Tea are very small^m. The Tea is a large Shrub, much like our Rose-bushes. It bears white Flowers, something like wild Roses. The Stalk and Branches of this Shrub are from the earth to the top covered with a prodigious number of Leaves, small, sharp, dented, and of five different sizes. The Leaves farthest distant from the Earth are the smallest, and in proportion as they diminish in size, they augment in value.

Eudox. A Plant valuable and famous in all ages is the Cedarⁿ. The Cedar is a Tree which resembles the Fir-tree, always green. Probably the compact texture of its Leaves preserves their Juice in the middle of Winter*. The Gum flows down from the Cedar. It is a stodorific Gum; and the *Egyptians* make use of it in embalming their dead, to give their Corpses, even after death, a sort of Immortality, which Nature bestows on the Wood of the Cedar.

The most precious and singular Plants have Maladies, as Animals have, in the course of their Vegetation. Let us make the Diseases of Plants the Subject of our next Conversation.

^m Rep. des Lett. Fev. 1685. Tom. 3. p. 107.

ⁿ Mem. de Trev. May 1703. p. 862.

* As Oil is an excellent Preservative against the Injuries of cold, so it is found to abound in the Sap of the more northern Trees; and it is this which in Ever-greens keeps their Leaves from falling. *Hale's vegetable Staticks.*



CONVERSATION IV.

Upon the Maladies of Plants.

Arist.  H A T are the Maladies of Plants, and whence do they proceed? I wait, *Eudoxus*, your opinion upon this head.

Eudox. Plants are indisposed, when an agreeable Juice is not distributed into their different parts. In that case you see them languish. These Languours have several causes, namely, the excess or defect of the nutritive Juices, the Malignity of these Juices, Fertility itself, and external Accidents.

1. The Excess of the nutritive Juices bursts the Vessels, and produces dangerous Effusions. Should the excessive Juice become grumous in the Tubes for want of Velocity, or Space to flow in, it will be stopt. The Juice which continually ascends from the Roots, penetrates and gradually possesses the Tracheæ, which are as it were the Lungs of Plants, and hinders the Commerce and Action of the Air. The Circulation is intercepted and the Plant dies as if it were suffocated.

2. The

2. The want of Juice produces the same effect. A great quantity of Juice is lost by Transpiration, as is observed in Plants, which sink down during the heat of Summer. If none comes from the Roots to repair this loss, the Fibres being destitute of Humours, are contracted, lose their Agitation, are dried up, and become incapable of receiving new Juices; the Plant languishes and dies. The Leaves grow yellow, wither and fall, when the Plant no longer furnishes them with a Juice delicate enough, and sufficiently prepared, to be filtered thro' their Fibres.

3. The Malignity of the Juices causes these languours and the death of Plants, by corrupting the Organs. Urine, for example, Lime-water, the Water of a Dunghil, a little too strong, and Beds too hot, burn up the Fibres of the Roots, by the excess of their corrosive Salts too much agitated, and put them out of a condition of receiving and filtering the Juices of the Earth. Is the Juice too viscons? It imbibes, thickens and fixes. It cannot flow, nor afford motion enough to the young Embryo in order to open it; and the Plant, far from bearing Fruit, perishes for want of nutritive Juice, which brings life into its Fibres, Stalk, and Branches.

4. The Fertility it self of Plants is sometimes a cause of their Maladies. Giving too much Juice to their Fruit they don't preserve enough for nourishing themselves. According-
ly

ly Trees too fertile are of less duration than others.

5. The external accidents which cause the Maladies of Plants are Incisions, Frost, Heat, Hail, the nipping of Insects, parasitical Plants, &c.

Incisions are hurtful, and even mortal to Plants, if one cut the Roots, or strip them of their Bark, or otherwise break the Wood, so that no more remain but the Bark; because in that case the Sap can no longer convey nourishment into the different parts of the Plant.

Frost, which dilates the Juices, as it dilates Water in Vessels which it breaks, tears asunder the Fibres of Plants, cleaves the Trees sometimes, and shivers them.

Heat violently agitates the Juices, and attenuates them; opens the Pores of Plants, and presses the Juices out of them by the excess of Agitation. The Fibres being destitute of Juices, are relaxed. The Plants without any force are pressed down by their weight, and languish.

The Hail bruises the Fibres of the Leaves, and extravasates the nutritive Juices. But why is Hail less pernicious when Rain falls at the same time?

Arist. Rain softens the Fibres, renders them more flexible, and consequently fitter to escape the violence of the Hail by yielding.

Eudox.

Eudox. As for the nipping of Insects, it produces Tumours upon Plants. These little Animals nip certain parts of Plants, and deposite their Eggs in them. The nipping is followed by an effusion of nutritive Juice. This Juice being shed, penetrates the adjacent Pores, where it is gathered into a Mass, dilates the Fibres, enlarges and puffs up the Pores, in the middle of which the Egg is at last hatched; and it is a Worm, or a Fretter, which finds its Nourishment already prepared in the Tumour. Hence these Species of Vesicles upon the Leaves of Elms, Gall-nuts, and the Grain of Scarlet.

The smallest Gnats attack the biggest Trees. They nip the Leaves of Elms, and therein deposite their Eggs. The Juice, whose ordinary course is interrupted by the nipping, is extravasated and produces Vesicles, sometimes as large as the Fist, and full of a Balm, in which one may see greenish Fretters floating, which have come out of the Eggs, but excellent for Wounds.

Gall-nuts are formed after the same manner upon the Leaves of the Oak.

Whence proceeds the Grain of Scarlet *? A kind of small Scarabæus, covered with a very fine Down, being attach'd to the Branches of the Scarlet Oak, which they call Kermes, and which is found in hot Countries, nips the Leaves near the Pedicle, and deposite in the

* Mem. de l'Acad. 1705. p. 339.

nipping the Egg of a Worm, which at last produces a small Fly. The Juice being stoppt by the nipping, and by the Egg, ouzes out. A Tumour arises. The Tumour forms Grains of about two Lines diameter. These Grains are filled with a Substance of a very lively red, which encloses the Egg; and this red makes a Crayon of Scarlet.

The parasitical Plants are often more pernicious than the nipping of Insects. They call parasitical Plants certain Plants which live only upon the expence of others, as the Moss and Mistletoe; for these are true Plants, and the Roots of these Plants are grafted into the Bark of Trees, draw Juice out of them, and rob them of their Sap for their own Nourishment; and by that means weaken, exhaust, and oftentimes destroy them.

The Mouldiness itself, which comes upon Plants, shut up in damp Green-houses, is some small parasitical Plants, of the Species of Mosses and Mushrooms, which the moisture causes to spring out in the Net-work of the Bark. Would you believe that things which appear mouldy, are as it were so many Meadows enamell'd with Flowers?

A Virtuoso* affirms, that with a Microscope he saw distinctly, in a spot of Mouldiness, upon the Cover of a Book, Flowers, some in Buttons, others blown, and some wholly in Flower.

* M. Hook Microg. J. des Scav. 20 Dec. 1666. p. 499.

The Seeds of parasitical Plants are extremely small; and the Winds convey them casually upon Walls, Roofs and Trees, where being favourably deposited, they grow up.

Arist. Must all these Maladies, *Eudoxus*, be without Remedy?

Eudox. Many Maladies of Plants have their Remedies, as those of Animals. Incisions, for example, sometimes diminish the excess of Juices. They move the Earth which covers the Roots; they let in more Air by moving it, and likewise cover it with Dung. A greater abundance of Juices penetrates to the Roots; the Air makes it enter by the action of its spring; and by that means they cure the defect of the Juices.

If the Roots become rotten, Cow's or Hog's Dung puts a stop to it. Are they mouldy? They wash them with clear Water, which tears and carries off the small Threads of Moss that are growing up. When a sort of Slime relaxes the Fibres, and causes Obstructions capable of making the Leaves fall off, Mould and Pigeon's Dung produce Fermentations and furnish Salts which unstop the Fibres, restore them to their former strength, and remedy the evil.

If some viscous Juices render Olive or Orange-trees flow, Hen's or Dove's Dung, Vine-ashes, and Lime itself being mixt in Autumn with the Earth, which covers the Roots of those Plants, afford Juices more
E 2
fluid

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fluid and efficacious, and hasten the Flowers and Fruit.

To avoid Mouldiness, they keep the Green-houses very dry. The Plants themselves which come out of hot Countries, are preserved during the severest Winters, in Boxes well glazed, and not much higher than the Plants. They store the bottom of these Boxes with Dung. They let fresh Air into them, while the Sun is in his force: this is always a dry Air without Moisture, which does no hurt to the Plant.

The Wounds of Trees are not always without Remedies. If by chance the Branch of a Tree is half broken, and the Bark be not wholly separated from it, they draw the two parts of the Branch together again, and make an apparatus capable of stopping the Sap, and of hindering the Air from drying up its Moisture, or from making any alteration in it. The Sap either finds, or makes itself free passages again, and the Branch recovers.

Are you now willing, *Aristus*, after having examined the Principles of Botany, that we try which shall explain the most Problems in it?

Arist. I accept your Challenge; but shall be well pleased first to recollect what you have said to me concerning Plants. To-morrow at three of the clock after Dinner, I shall wait on you in the Physick-Garden.



CONVERSATION V.

Wherein is explained a great number of curious Facts and Problems, which relate to Botany.

Eud.



OR what use does it serve, *Aristus*, to move, dig, labour, dung and dress the Earth so much?

Arist. The Earth being prepared after that manner, has thereby the more Interstices, proper for transmitting the Rain, Vapours, and Nourishment to the Roots; more Salts disengaged and fit for fermenting and furnishing Juices; and more Air fit for seconding the Fermentations in the Earth by the action of its Spring, and for making the Salts and Water enter into the Fibres of the Roots.

Eudox. Whatever facilitates the opening of the Seeds by its Action, causes or hastens the growth of Plants. Hence divers Secrets of Agriculture, of which the Journals of the Learned make mention.

1. If we burn or calcine Earth, and after that water it with a good deal of Water, this

Earth soon becomes fertile, and bears a thousand different Plants^a. The Heat disengages the Seed from the terrestrial Particles, opens its Pores, and disposes it to receive the nutritive Juices. *Virgil* was equally a Poet and Philosopher, when he said,

*Sæpe etiam steriles incendere profuit agros,
Atque levem stipulam crepitantibus urere
flammis ;*

*Sive inde occultas vires, & pabula terræ
Pinguia concipiunt ; sive illis omne per ignem
Excoquitur vitium, atque exudat inutilis
humor ;*

*Seu plures calor ille vias, & plurare laxat
Spiramenta, novas veniat quæ succus in her-
bas, &c.*

2. ^b Steep in Aqua-vitæ some Seeds, Lettice, Colliflower, Sallet, &c. Mix with Mould some slaked Lime reduced into Powder, with a little Pigeon's Dung ; in twice 24 Hours you will have Lettice, Colliflowers, Sallet, &c.

3. ^c Would you have Parsley ? Soak some Parsley-Seed in Vinegar, and after having sown it in good Earth, throw upon it plenty of the Ashes of Bean-cods ; after that besprinkle the Earth with Spirit of Wine, and cover

^a Hon. Fabri. l. 2. de Plantis, Prop. 99. p. 58.

^b Journ. des Sçav. 9 Sept. 1675. p. 239.

^c J. des Sçav. 1666.

it well with Linnen-cloths. The Parsley will spring up out of the Earth in few hours.

4. If you design to raise Pease and Beans quickly, nothing more is required than to put them into hot Oil for the space of nine Days, and then to grind and sow them. The Beans and Pease will spring up in an Hour^d.

Arist. They compare the Roots to the Stomach of Animals.

Eudox. Because the Roots, like the Stomach, receive the Nourishment, digest, alter and change it into nutritive Juice. Accordingly whenever the Nourishment has past from the Roots into the Stalk, one may observe, that it has taken a particular Odour, Colour and Taste^e. The Action of the Air meliorates the Juices in the Trunk. The Heat of the Sun refines them there, by the Agitation and Division of their Particles. Perhaps you will not believe what several Authors have advanced, that Plants are formed in the Body of Man. Nevertheless the *German*^f *Ephemerides* say, that a Man voided small Mushrooms from time to time, as others do Stones, and that they found, near the right Kidney of a Man 55 Years old^g, a Cluster of small Mushrooms. A *Dutch*-man speaks of a Mushroom formed in the Bladder as big as an Hen's Egg. A Cane of Sugar, which an Author tells us had

^d Journ. des Sçav. 7 Fev. 1684. p. 47.

^e Mem. de l'Acad. 1707. p. 281.

^f Journ. des Sçav. 9 Fev. 1679. p. 35.

^g Journ. des Sçav. 13 Fev. 1679. p. 48.

taken root and sent forth Leaves in the Stomach of an Elephant, is a thing too surprizing to appear credible. May not one swallow Seed, which may find in the Chyle or nutritive Juices, particular Juices capable of opening it?

Would you believe, *Aristus*, that in *Canada* they have extracted a Species of Sugar from the Maple-treeⁿ?

Arist. There are Seasons wherein the Vessels of Trees are full of Juices; as the Spring and Summer. This excess of Juice is the Sap. The Spring is the Season of the first Sap; and Summer is the time of the second. In the time of the Sap several Trees throw out their Sap abundantly, if their Bark be but a little wounded. The excess of Juices ouzes out and distils thro' the vent by the Motion of its Elasticity and Liquidity. Hence the Balms and Turpentine, which proceed from Pine-trees. Now if we see Trees so full of different Juices, why may not some be found which bear a Juice of which they may make a Species of Sugar?

In the time of the Sap the Trunk is easily stript of its Bark.

Eudox. Because the Juice, which flows in abundance betwixt the Bark and the Wood, detaches the Bark from it by its Motion and Elasticity.

ⁿ Mem. de l'Acad. 1707. p. 277.

The chief Production of Branches happens at the top of the Trunk, and when the Tree is lopped, one scarcely sees any new Buds but where it was lopped.

Arist. Because probably the Sap being thrown directly from below upward, is not sufficiently stopt till it be at a certain height from the Earth, neither does it receive an oblique Direction strong enough to turn it aside, and force the Buds that are towards the out-part to shoot out and open.

The hardest and oldest Trees ordinarily shoot out their Leaves later than the others.

Eudox. Because their parts being more close and compact, the Sap finds in them passages less free; and the budding is later in them than in Trees whose parts are more flexible, and more impregnated with Juices.

What think you, *Aristus*, of what we are told of an Aloes, which after having been in the Garden of *Montpelier* time out of mind, suddenly shot out a Stem when it seemed to be withering and dying, so prodigious that in less than 24 Hours the Stem arose to the height of 20 foot, with a noise of Thunder.¹

Arist. Perhaps the hardness of the Bark or Covering had for a long time retarded the rise of the Stem, it might have been folded, the Juices being impregnated with Air, had penetrated into the Fibres with violence; a great quantity of other Juices had remained

¹ Mem. de Trev. Nov. 1708.

about the Roots, and finally the sudden Rupture of the Bark or Covering, had at once afforded a free Passage.

The Stem being shot out by some violent Fermentation, and by the Spring of the internal Air extraordinarily compress'd, must have been too quickly explicated with its Leaves. The Juices heaped up round the Roots had entered rapidly into the Plant by the excess of Fermentation. The Fermentation and this abundance of Juices produced this sudden Accretion. And the suddenness of the Explications would cause in the Air that impetuous and alternate Motion which made the Noise.

Eudox. However that be, Honey or a Species of Manna is found upon the Leaves of certain Trees. They have often remarked upon Leaves, and particularly upon Leaves exposed to the Sun, a viscous, oily and sweet Moisture, of which no traces were to be seen upon the Plants till after the Sunrising*.

They have several times observed the Bees gather this Matter upon the Leaves of Trees, and load themselves with it as they load themselves with a Juice of the same nature, which is found upon the internal Surface of the bottom of Flowers. Now this Juice is a Species of Manna or Honey. Accordingly Honey, as *Pliny* has remarked, retains the Taste of the Plants from which the Bees have gathered the Juices. Hence in certain places it is per-

* Mem. de l'Acad. 1707. p. 277.

nicious,

icious, in others moderate, and in some exquisite. But whence proceeds this Species of Honey or Manna? Is it from the Dew, as the Antients believed?

Arist. It is the most exalted and elaborate part of the nutritive Juice of Plants. This part of the Juice being refined and rarefied by the Heat, is thrust into the Fibres of the Leaves; and forced to come out, it transpires thro' the less contracted Pores. Is it not true that the Manna of *Calabria* is the extravasated Juice of the Ash-tree^k? Hence Honey retains the Taste of Plants upon which it was gathered.

Do you believe, *Eudoxus*, that Leaves are very necessary or useful to the Fruit?

Eudox. The Juices are brought to perfection by circulating in the Leaves; they are thereby the more delicate. Besides, Leaves serve to defend the tender Fruit from the injuries of the Air. Accordingly when the Caterpillars devour and consume all the Leaves, you see the Trees languish and bear only abortive Fruit.

Arist. But why are the Trees, which are too fertile, the least durable?

Eudox. Because in proportion to their bigness they expend too much Juice in nourishing their Fruit, and do not reserve enough of it for nourishing the Roots, Trunk, and Branches, as we have already observed. Accordingly, they not only cut Vines in order to make them

^k Mem. de l'Acad. 1707. p. 278.

shoot out more Branches, but also that they may not bear too much Fruit, as Hedges of low Vines do, which have never been cut. They bear a great quantity of Fruit. For which cause the Vine-dressers, who dress Vines which they farm, sometimes neglect to cut them the last years of their Leases, or cut them too long, that so they may have the more Fruit, and this is what they call *drawing to the Wine*¹ *. But if they neglect to cut the Hedges for two or three Years, they decay thro' the continual bearing and consuming their nutritive Juices.

Oftentimes when they cut the great Branches of Trees, they cover the Wound.

Arist. That is to hinder the Juice from running out, and to oblige it to diffuse itself into the Substance of the Trunk or other Branches. They likewise make a sort of Dressing for the Wounds of Trees which they have grafted, in order to reunite the Juice, and to constrain it to run thro' the Scyon, and by its thickening, to make a kind of Cicatrice, whose Edges swelling, recover the Wound.

Grafted Olive-trees from which you cut off the Bark below the Graff, without cutting the superiour Branches, bear more Fruit that Year.

Eudox. Probably because the Juice, which makes the Flowers and Fruit, is that particularly which passes through the Pith, as we have

¹ Mem. del' Acad. 1707. p. 284.

* *Tirer au Vin.*

observed ;

observed; and because the Bark being cut, the Juice which that ought to convey, is filtred and mixed with that of the Pith.

Have you observed, *Aristus*, that Orange and Fig-trees being planted in small Boxes, bear the more Fruit^m?

Arist. Because in the small Boxes the Sap of the Orange and Fig-trees not finding room to extend itself in the contracted Roots, is employed in greater abundance in making the Flowers and Embryo's of the Fruit to bud.

Why do they make the Beasts eat that Corn which bears too many Leaves?

Eudox. In order to force the nutritive Juice to filter into the Stalk, and to make it run up into Straw. Bnt lastly, what causes the Maturity of Fruit?

Arist. The Heat divides and attenuates to a certain degree whatever is too aqueous in Fruits, and renders the imperceptible Particles finer and more proper for striking the Taste without hurting it; and this is maturity.

But do you believe, *Eudoxus*, that there is in Plants an imperceptible Transpiration?

Eudox. Why do we see Plants incline toward the Earth, and flag in the Heat, and resume their former vigour when the Cool returns? Because the Heat throwing out of the Plants, by an imperceptible Transpiration, a great quantity of Corpuscles, the Fibres are emptied, relaxed, lose their firmness, and

^m Mem. de l'Acad. 1705. p. 335.

yield to the force of Gravity for want of Corpuscles or Spirits capable of swelling the fibrous Tubes. Therefore when the Bodies of Animals have sweated very much, they grow faint, because an excessive Transpiration has deprived them of the Spirits necessary to animate the Body. But should the Cool give new Juices and new Spirits to Plants, they swell the Tubes, fill and straiten them again ; and this is to restore Plants to their former vigour. Thus when fatigu'd Animals are refresh'd, new Spirits fill the Nerves, and restore to them their former vigour and firmness.

The Motion of the Turnsole, which seems to follow the Sun, does it not proceed from an excessive Transpiration?

Arist. The parts of this Flower turned toward the Sun, being relaxed by the excessive Transpiration of their Juices, while the parts turned away from the Sun are not at all so, or at least much less, find themselves constrained to sink under the weight of the Leaves and Flowers, and to suffer them to incline toward the part which affords them the weakest Prop. This part is toward the Sun. Hence the Turnsole seems to follow the Sun, or to turn about at the pleasure of this Planet.

Eudox. It is likewise probably the action of the Sun which makes some sort of Roses in *China* appear to change colour twice a day, and to be sometimes white, and sometimes of a fine red mixt with a little Violet like the Purple.

ple. The texture of the Fibres being changed by the action of this Planet, by the difference which it causes in the Juices, remits the Rays differently, and the Rays being differently modified and matched, make those different colours, which the same Flower alternately presents to the Eyes.

Arist. But why does the Convolvulus shut up in the night-time, while the Marvel of Peru is blown?

Eudox. That proceeds from the different extensibility of Plants. If Nightshade has Pipes hollow, flexible, and as it were outwardly cylindric, they will swell in the Night, become strait, open the Flowers, and blow. The Sun will dry up those Tubes in the Morning, the opposite sides of the Flowers will be drawn back by the action of their Spring, and the Flowers will hide themselves in the day-time. By a contrary Disposition of the Tubes, the Convolvulus will shut up in the Night, and open in the Day.

A young Plant shut up in a Cellar, or in a Room, whose Window is open, turns as of itself towards the Air-hole or Window.

Arist. The young Plant being impell'd by the Juices, which circulate in its Substance, and by the Air which surrounds it, and being very flexible, ought to turn its Stalk and Branches toward that side where the Pressure is least. Now the Pressure of the Air is least toward the Vent and Window; for there the
Air

Air yields oftner and more easily, because it has there a neighbouring Passage, and is more rarefied and warmer. By the same principle Trunks and Branches seem to avoid Espaliers.

But whence can the twisting of the Hops and other Plants of this sort proceed?

Eudox. These Plants being too feeble to support themselves, and meeting with a Body proper to sustain them, lean upon it; the tender Fibres which touch the Body that serves them for a Prop, being contracted by the Compression, shrink a little, while the external and opposite Fibres are lengthened. This contraction of the Fibres determines the parts, which grow up afterwards, to stay themselves after the same manner. Their Fibres are alike contracted, and produce the same Effect. Hence the twisting of Plants.

I don't know whether you have seen Branches of Trees press'd down by the weight of Oysters. Father *du Tertre*, a Jacobine, in his History of the *Antilles*ⁿ, says, that he saw in the Island of *Guadeloupe*, several Trees so loaded with Oysters, that the Branches of them broke, being bent down under the Weight: and the same hath been observed near *Plymouth*^o.

Arist. Probably the Waves of the Sea, which are spread over those Branches, deposit on them the Seed of Oysters, which is attach'd

ⁿ Journ. des Scav. 25 Avril, 1667. p. 88. Hist. des Antilles.

^o Hist. of Nat. Rarities of *England*, Journ. des Scav. 1667. 13 Juin, p. 115.

to them ; and the Oysters being hatch'd, are nourished there so much the more easily, because the Flux and Reflux of the Sea refreshes them twice a day.

Eudox. Plants are often a Prey to Insects ; but their being impregnated with certain Salts is sufficient to protect them, because those Salts are hurtful to Insects, whose Fibres they tear into pieces. For example^p, they boil in a Pail of Water, for the space of half an hour, Rue, Wormwood, and *Virginia* Tobacco, an handful of each ; after that, they press out the Water, and with it they water Plants three or four times when they are in Blossom : this is enough to secure them from Caterpillars and black Flies ; and an inlaid Floor being soak'd with water, with which one has mix'd corrosive Sublimate, is inaccessible to certain Worms, which otherwise would eat into it^q.

One thing still, which at first may seem surprising, is, that in the *Antilles* every thing shoots forth during the Winter^r.

The Fields there are then covered with green. On the contrary, in Summer, the Leaves fall off, and the greatest part of the Plants die. One sees the Reason of it very soon. In those Islands it is hot even in the Winter itself, and in Summer the Plants are burnt up with excessive heat.

^p Journ. des Scav. 3 Juin. 1675. p. 156.

^q Hist. de l'Acad. 1705. p. 38.

^r Hist. des Antilles. Journ. des Scav, 1667. p. 88.

Would you believe, *Aristus*, that Plants die at last for want of Respiration? The Respiration of Plants is one of the Observations of *M. Malpighy*, confirmed by a later Author in a very ingenious Discourse upon this Subject^f.

Arist. I only waited, *Eudoxus*, for your Opinion upon the Respiration of Plants.

Eud. 1. When we see Fish die for want of Air in purified Water, we reasonably judge that they respire in Water itself. Now Plants die as Fish do, in purified Water; and Water impregnated with Air preserves their life. Therefore one may say, at least with some probability, that Plants respire.

2. We are convinc'd that Insects have need of Respiration in order to live, because Oil which stops the Ducts of their Respiration, makes them die. Now the mere smell of Oil is sufficient to make several Plants die; a drop of Oil being put to their Roots is sufficient to kill a great number of them. Therefore it is probable that Plants have need of Respiration as well as Insects.

3. In short, if Plants attract the Air, and reject it successively, this is a sort of Respiration: But, 1. Plants attract the Air; for it is certain that those green Branches, which while they burn on one side, send forth on the other a Puff like to that of the *Æolipile*, contain very much Air. Fruit whose Substance is spongy,

^f Mem. de Trev. 1712. Mai.

as Citrons and Oranges; are hardly any thing else than a number of small Corners full of Air. Green Peas and Beans newly gathered, are inflated even to bursting by the dilatation of the internal Air in an Air-Pump. 2. Plants throw out Air. As they transpire considerably, and incessantly receive new Particles of Air with their Nourishment, if they always remain'd the same Air, the Air ought to swell them strangely, break their Fibres, and make them fade away.

4. Lastly, to receive and reject the Air alternately is Respiration. But Plants receive and reject the Air alternately. They cannot dilate and contract themselves alternately, without receiving and rejecting the Air at the same time; and they do dilate and contract themselves after that manner. The Juices propelled by Fermentation into the Plants ought to dilate the Tubes, and the Elasticity ought afterward to contract them. Therefore, &c.

Accordingly in the internal part of the Roots they perceive two sorts of Ducts, the one which receives the Juice, and these are the ligneous Tubes; the other, which carry the Air into the Cellules, are the Tracheæ. These Tracheæ very much resemble those of Insects, and are dispers'd after the same fashion; being disposed along the Plant, formed of a minute Lamina, sometimes united in their course, and sometimes widened in form of small Cells. These Cellules are probably Reservoirs and

Lobes, if I may so call them, into which the Air is conveyed through the Tube of the Trachea, in order to pass thence into the Juices, and to give them that fluidity which is requisite for their Circulation, and conveying Life to the whole Plant. This Air, which entered in the Dilatation, issues out at last in the contracting of the Plant. Hence in some small Pores of several Sponges, which come from the Sea, there is observed a kind of Motion of Diastole and Systole^t.

Arist. I believe, *Eudoxus*, that so great a number of Effects being explained, may furnish us with the Knowledge of an infinity of others.

Eudox. The Knowledge of the human Body, and of Plants, affords us a general idea of the Structure and Mechanism of the Bodies of Animals. Nevertheless, Animals deserve at least one Conversation.

^t Hist. de l'Acad. 1710. p. 73.





CONVERSATION VI.

Upon Animals.

Eud.  HE generality of Mankind make no great account of Animals ; they tread Insects under their feet : yet whenever we look upon the smallest Insects, or vilest Animals, as Philosophers, the Mind is seized with admiration. What variety of Species ! We quickly see that the bountiful hand, which formed them, must have been guided by an infinite Wisdom.

Arist. Probably all Animals proceed also, as well as Men, from Sperm or Eggs, which the Author of Nature placed at first in the first Animals of every Species, and which want only to be hatched and unfolded.

Eudox. You give them a noble Origine. Some great Philosophers have vilified the original of Insects so far, as to attribute it to Corruption. Corruption hatches them ; but this is after the Flies have deposited their Eggs. Thus such Bodies as seem to engender small Insects, when they are corrupted in a part accessible

cessible to the Flies, produce none when they happen to be corrupted in a part to which the Flies have no access *. Could Chance, a fortuitous Concourse of Particles, produce Beings so regular, and in which Art is so much superior to the understanding and skill of Men?

The Eggs being once formed, we conceive how the Embryo is explicated. How is it hatched, for example, in an Hen's Egg? A certain degree of Heat agitates the liquid Matter, which encloses the Embryo; the Heat divides this Matter, attenuates, digests, and makes it flow through the Navel into the Body of the little Animal. The Vessels which receive it successively, direct it toward different parts of the Body, in order to convey to them Nourishment, Accretion and Life. Do you know, *Aristus*, in what manner they hatch Eggs in *Agypt*, without the Aid of the Hen?

Arist. I shall be glad to learn it.

Eudox. It is equally curious and certain. I learned it from a Person who saw it †. There are Ovens for Chickens. These Ovens are in hollow places and built in form of a Dortoir, with an Alley in the middle, and four or five Rooms on each side. The Door of the Alley is low, narrow, and stopt with Tow, in order to preserve the Heat. The Rooms are four or five foot in breadth, and fifteen in length, or

* Le Clerc. des Animaux, c. 3. Redi. des Insectes, p. 135.

† Mem. des Missions de la Comp. de J. dans le Levant, p. 79. Tom. 7.

thereabouts;

thereabouts; they have two Stories, the one level with the ground, the other has two floors. The lower one has a round hole in the middle, and the other is vaulted like a Dome, but open. Instead of a door, every Story has a little window, a foot and half round.

At first they put four or five thousand Eggs at least into the lower Story. They kindle a Fire in the upper Story, for an hour in the Morning and another in the Evening, during the space of eight days. This Fire is made of Cow's Dung, or the Dung of other Animals, dried and mixt with Chaff. While the smoak comes out of the hole in the upper story, they close up with Tow the round hole of the Dome, and the little window of the lower story, that so the heat may be communicated thro' the vent of the floor to the story where the Eggs are.

After the eighth day, they suppress the Fire. They put a part of the Eggs into the upper story; where the Fire was daily kindled. They shut up the small Windows of the two Stories. They half open the upper hole of the Dome to let in Air. The Eggs are thirteen days in this condition of an agreeable and concentric heat, which prepares, insensibly digests the nutritive Juice, and makes it flow into the substance of the Embryo. The eighteenth day after operation, " you may see
" thro' the Shell the Embryo stir and nourish

“ it self with the Yolk, which it sucks in
 “ thro’ the Navel. The twentieth the young
 “ Chick splits the Shell with its Beak.” He
 that manages the Oven, widens the gap a little
 with his nail. The one and twentieth at noon,
 or the two and twentieth in the morning, the
 Shells are broke, and the Chickens are freed
 from their Prisons. There is at once an Army
 of little Volatiles. Yesterday you might have
 seen thousands of inanimate Shells, and to-
 day they are thousands of small living Birds,
 which have no sooner seen the light than they
 know how to discern and lay hold on what
 may preserve their life.

The wonderful Operation of Chicken-
 Ovens can only be performed during the Au-
 tumn and Winter. The Spring and Summer
 are too hot.

Arist. I admire the Art which hatches thou-
 sands of Chickens at the same time. Would
 it not succeed in *France*?

Eudox. The Directors of the Chicken-Ovens
 have offered themselves to come and build
 some here, answering for the success.

However it be, the idea which we have of
 our own Body may be of use to us in pene-
 trating into the Mechanism of the Bodies of
 Animals. But let us not attempt to unravel
 all that is curious and singular in every Species.
 Life would be too short. Let us however
 recollect some traces of the History of Ani-
 mals.

For

For my part, I am charmed when I read the Observations of *Aristotle* upon Bees^a, or when I observe in a Bee-hive of Glass, or in a Flower-garden, the Structure of Bees, their Number, Government, Functions, Industry and Passions. Bees^b have two Jaws or Jaw-bones in the Head, and a Trunk near the Neck; six Feet; a small Bladder destin'd to receive and bear the Honey, which they suck with the Trunk, and reject thro' that part of the Head which is between the two Jaws; and a Sting in their hinder part. They make use of their Sting not so much for attacking others, as defending themselves. It terminates inwardly in a little Bladder full of a venomous Liquor, and is hollow. When the provok'd Bee stings any one, the Liquor being compressed, issues out thro' the passage near the point, flows into the Wound, and inflames it. Nevertheless, if you draw it out quickly, little venom enters, and there happens but a small tumour. If the Sting, being struck in, is grappled in the pricking, it remains there, the Body of the Bee is torn in the effort which it makes to fly away after it has avenged it self; and the Wound which it has made in you, costs it its Life: *Animasque in vulnere ponunt*^c.

^a Book 9. of the Hist. of Animals, c. 40. Book 3. of the kinds of Animals, c. 10.

^b Mem. de l'Acad. 1712. p. 299.

^c Virg. Georg. lib. 4. v. 238.

Oftentimes there are 8 or 10 thousand Bees in one Hive; they have counted as good as 18000. They find among them a considerable number of Drones, which are ordinarily one third bigger and longer than the Bees, and without a Sting. Sometimes one sees in a Swarm two or three Bees at most which are longer, and of a more lively colour than the Drones, but not so large in proportion to their length. Commonly there is only one of them, which is easily distinguish'd from the Drones by its Colour, Bulk and Shape; and this is the King. This King is doubly the Father of his People, since he knows how to make Plenty and Order reign in his Dominions, and because he alone has Fruitfulness to his share. Amongst the People of the Bees some are destin'd to go and gather Wax and Honey upon Leaves and Flowers; others to take in the Crop, and to raise the Edifice of the Combs; others to polish and perfect them; and some to hinder the indiscreet and rash Insects from coming to disturb the publick order and repose.

The Wax which is gathered upon Flowers, seems to be the Dust of the Stamina. The Bees which gather the Wax, make it pass into a Cavity which they have in their Hind-Legs. Sometimes in order to carry off small Particles of Wax with all the Hairs, wherewith their Body is covered, and to load themselves on all sides, they roll themselves upon the Flowers.

Flowers. When they arrive at the Hive, they make themselves heard by a motion of their Wings; and others often come and assist them to unload, take the Wax, temper it, knead it, and go to work with it.

For the most part they begin the Edifice at the top of the Hive. It consists of Combs. The Combs are Planes perpendicular to the Base of the Hive, and perforated with a number of Holes. The Holes are Hexagons, or small Cells with six sides, every one of them fit for the containing a Bee. In proportion as those which build the Walls of the small waxen City advance their work, others are employed in perfecting and polishing it with their Jaws; they turn the Angles after a curious manner, plain the Surfaces, finish the Sides and Bases, and compleat the Whole.

Oeconomy stores up the superfluous Particles of Wax in some Cells, while Fore-cast goes in quest of Honey. The Bees, which are charged with the care of gathering it in, consume only a small portion of it for their own nourishment, carry off the rest in their little Bladder, and deposite it in the Cells, which are as it were the publick Magazines, where the People find sweet nourishment in Winter, when they have a mind.

The Bee-holes for the most part are the Cradles of the young ones.

Arist. But how are the young ones brought forth? How are they reared?

Eudox.

Eudox. The King, or rather the Queen of the Bees, (for she is the Mother of the Bees) being attended with ten or twelve Bees that are most considerable, and walking with a grave and sedate pace, visits the Bee-holes. She hath been observed ^d to enter into eight or ten Cells, one after another, and to leave in every one of them a little white Worm, or an Egg. While the great Bee is in a Cell, those who attend her are disposed in the form of a Circle; and if you saw the Action, Air, and Motions of the Retinue, you would say that they were forward to caress her with Feet and Trunk, and applaud her on account of her Fertility. The teeming Bee places in the largest Holes the Eggs which ought to produce the Drones, and the Kings or Queens. After four days the heat of the Hive makes the Eggs to hatch small Worms. Sometimes the Bees sprinkle a certain Liquor over these little Worms. The Worms are explicated, and they bring them Honey for nourishment. After eight days they stop up the Holes with small coverings of Wax, very thin. About twenty days after the Eggs have been laid, you see young Bees bore thro' the door of their Cells with their Jaws, make themselves passages, fly away the same day, being probably allured by the scent of the Honey and Wax, gather the Wax and Honey upon the Flowers, and with dexterity deposite their

^d Mem. del'Acad. 1712. p. 313. M. Maraldi.

Harvest in the Magazines of the Hive. Scarcely are they brought forth, but they know all the customs, and all the usages of the Mansion which has seen their Nativity. Already are they as zealous for the publick good, and as skilful, as those which have grown old in the exercise of all the Employments, thro' which one may pass in the Empire of the Bees.

But would two Swarms live there any long time together? One must give place. It is scarcely departed, when that which remains sets itself to produce a new one. They labour night and day in the Hive, in Summer, peaceably enough. But Peace cannot last long amongst Men, why should it reign always amongst Animals? From time to time there are single Combats amongst the Bees; and toward the end of Summer, when the crop of Honey is not sufficient for Winter, there is sometimes a general battle. The sight of the Drones, which they conjecture to be the Males, but which then become useless, provokes the people of the Bees, and the indignation of this people, however wise, becomes terrible. They are seen to throw themselves in crowds upon the Drones, and to drive away or kill them. There is no quarter; their victorious fury does not spare the young Drones themselves. They pull them away, even those little ones, from their holes, that they may cut them to pieces; they tear them unmercifully; and in a short time you see the bottom
of

of the Hive covered with their scattered members.

But Bees have a dreadful enemy in the cold. In order to secure themselves from it in Winter, they agitate themselves; and this agitation causes a heat, which is communicated to the glasses of the Hive, where it is very perceptible.

These Observations are curious; they affect me; I know not whether they make the same impression upon you.

Arist. Can one observe, without amazement, in these small Insects, so much Forefight, Industry, Love of order, and pacific and warlike Inclinations? My imagination collects a species of Animal, which discovers much less understanding, but is infinitely bigger; and that is the Whale. I love to fancy to myself a Whale of 60^c, 100, 200 foot long: Natural History assures us that some of them have been seen of this bigness^f, and they say that the Head makes up a third part of their Body^g.

Eudox. If these huge Animals were as furious as the provok'd Bee, with a blow of their Tails they would make Shallops fly in pieces, and would be terrible to Ships.

Arist. Luckily the Whale does not make use of its strength to do any mischief. It wishes

^c Mem. de Trev. 1717. p. 2003.

^f Journ. des Sçav. 1683. p. 351.

^g Mem. de Trev. 1717. p. 2003.

no evil; not even to those who think on nothing else but to destroy it. It flies continually, and this is what emboldens Avarice to pursue it. One Whale alone, of about 60 foot in length, yields an hundred Hogsheads of Oil. Thus the North Sea is sometimes covered with between seven and eight hundred Shallops, employed in fishing for Whales. There are in one Shallop six or seven Men. One of them, who is upon the fore-part, holds in his hand a Harping-Iron, which is at the end of a Rope of some hundreds of Fathoms. The Harpiner darts the Whale. The Whale being wounded, contracts, and being contracted, becomes heavier than an equal volume of Water; being heavier, it sinks and runs away with rapidity. The Rope runs, the Rowers who hold it, follow. The Strength of the Whale is at last exhausted by the loss of Blood. When they perceive it to draw weakly, several Shallops unite together to draw it back, and they put an end to its life by darting it with Spears ^a.

Eudox. You seem, *Aristus*, to have reserved your admiration for the biggest Animals; and yet the smallest are those which surprise me most. Is it not astonishing that the surface of the Earth is overspread with an innumerable multitude of Animals almost infinitely small, who find their nourishment both in the Juice of Plants, and also in

^a Mem. de Trev. 1717. p. 2004.

Minerals?

Minerals? The greatest part of Minerals and Plants being infused in Water, make it swarm with Insects invisible to the naked Eye. I have seen thousands of them with a Microscope in the hundredth part of a Drop. They swarmed in it, met one another without clashing, and leapt about at freedom, now toward one side, then toward another. These living Atoms must have in their inexpressible smallness, Feet, Bowels, Heart, Eyes; Organs for Nutrition, Motion, and Generation; Blood, Arteries, Veins, Nerves, and Muscles; and the various members of every Insect, tho' infinitely small, are to that Insect as those of a Whale are to the Whale. If it requires a Wisdom so far above human Understanding to give Organs to the Whale, what Wisdom is there not necessary to organize Bodies so infinitely small?

Arist. An Animal more singular than either the Whale or your infinitely small Insects, is the wild Man of the Island of *Borneo*. It is difficult to imagine to one's self a Monster which under the human shape is only a Beast; nevertheless here is the extract of a Letter written from the *Indies* the 10th of *January* 1700.¹
 “ The 19th of *May* 1699, being at the Road
 “ of *Batavia*, I my self saw upon the *London*,
 “ an *English* Frigate coming from *Borneo*,
 “ one of those Savage Men, who was only
 “ as then three Months old, about two foot

¹ Mem. de Trev. 1701. p. 184.

" high, cover'd with Hair, but still very short.
 " He had a round Head, and very like to that
 " of a Man; Eyes, Mouth and Chin, a little
 " different in Shape from ours. I dare not
 " give him a Nose. When he lies down, it
 " is upon his Side, upon one Hand. I found
 " the Pulse in his Arm such as we have.
 " The Stature of those Animals at full growth
 " equals that of the biggest Men. Mr. *John*
 " *Flower*, Captain of the Vessel, told us
 " that he had killed one with three Balls.
 " They run swifter than Deer. They break
 " down the Boughs of Trees in the Woods,
 " which they make use of to knock down
 " Passengers. When they can kill any one,
 " they suck his Blood, which they relish as
 " the most delicious Drink. When I went to
 " *Malacca*, there were three of these wild
 " Men of *Borneo*."

If there are Sea-Men, the Man of *Borneo*
 is not an incredible thing. But M. *Clouer*
 says, that he had seen in a River of *Virginia*,
 a marine Monster which appeared with the
 Tail of a Fish, but having the Head, Arms,
 Air and Visage of an *Indian*^k. They affirm,
 that in 1671, six Persons saw another near
Martinico, which had the Eyes somewhat
 large, the Nose flat, the Face full, Hair lank
 and smooth, mix'd with white and black, and
 flowing upon the top of his Shoulders, with a

^k Journ. des Scav. 1676. p. 351. Copied out of an *English*
Journal.

grey Beard, which hung over his Breast; the lower part terminated in a Tail, large and forked. A Certificate made before the Notaries of the Country attests the fact.

Eudox. The Idea of these sorts of Monsters brings to my mind another Species which is mentioned in the History of the Knights of *Malta*¹. It was a terrible Serpent, covered with Scales, except under the Belly. This horrible Beast laid waste a Country of the Island of *Rhodes*. The Knight of *Gozon* caused an Image to be made of it, in wood or pasteboard, very much resembling it. He trained up two young Mastiffs, and accusom'd them not only to see this Figure, but to leap at it, and seize it under the Belly. When he saw his Dogs train'd up for this kind of fight, he had the boldness to attack the Monster itself with his warlike Mastiffs. The Knight was confounded at first; but his Mastiffs seeing nothing that was new to them, threw themselves without dread upon the Belly of this terrible Animal; they fastened themselves to that part which was accessible, and tore it to pieces without letting go their hold: and the Knight, after having expected to perish in the conflict, at length obtained his end with the assistance of his Dogs, destroyed the Monster, and freed the Country from it.

¹ Hist. des Cheval. de Malte, Tom. 2. 3 Edit. p. 194. par M. de Vertot.

Arist. You may see in a Letter written from the *Indies*, a short time ago, by a Missionary ^m, a Stratagem something like this, which had the same Success. An enormous Monster *, a Serpent of a prodigious size, whose length was about eight or ten foot, had his retirement in a Mountain near a River. When he espied a Shallop, he went under water to overturn it, and at his leisure devoured those who were on board. A Criminal, who had his life promised him, thought of fastning a Rope to a Tree by one end, and Men of Straw with the other, which appear'd upon the surface of the water. These floating Men were filled and bristled with Hooks, Tenters, and Grapples. The Monster being allured by Figures like those with which he had often fed himself, failed not to seize them greedily, and fasten himself with the Grapples. In vain did he attempt to disintangle himself, he only hooked himself the faster. This destructive Animal was torn to pieces by the Tenters and Grapples which he swallowed down, and the Country was delivered from a Monster fatted with human gore.

Eudox. I saw this morning ⁿ a Monster less dreadful, but a true Monster. It is a Roebuck,

^m 18 Recueil de Lettres édifiantes & curieuses de quelques Missionnaires, p. 49.

* As to the several Monsters here mentioned, little regard is to be had to the Accounts of them, they being generally delivered to us by Missionaries, who are for the most part very romantick.

ⁿ 13 May, 1729.

seemingly three or four months old at least, with two Heads upon one Neck. The two Heads are well shaped, and almost of equal bigness. Each Head has two Eyes and a Mouth. The Animal seems equally to have made use both of the four Eyes and the two Mouths. The two Heads, after having made a pretty large angle, are united upon the extremity of the Neck. They have three Ears, one double and two single. That which is in the part where the Heads join, has two passages, and makes a triangle with the others. Probably two Eggs or two Embryo's have been laid close to one another, and the juices by making a free passage to circulate from the one into the other, at least from the one into the head of the other, have insensibly fortified their Union, and formed this monstrous Animal in the Forest of *Compiègne*. The King lately caught it there in hunting. Could the Monster perish more honourably? Poets can make the finest and most lucky Allusions and Predictions. May not Philosophy itself, which pretends to say nothing but truth, make some without any hazard?

Arist. This real and rare event renders probable, at least in some measure, what the *German Ephemerides*^p have said concerning a Hare. This famous Hare had two Heads, the one above the other; and eight Feet, four under the Belly, and four upon the Back.

^p Jour. des Scav. 1677. p. 118.

When it was tired with running upon four Feet, the Writers of the *Ephemerides* made it run upon four others, till at last after having escaped many dangers by that means, it fell into the hands of a Prince.

Eudox. Probably Nature sometimes produces these kinds of Monsters in order to furnish variety of pleasures to Princes, who only taste those that are innocent.

But finally, can these Animals, which have something in them so surprizing, be only Machines? Can they have Reason?

Arist. One may read in the Journals of the Learned^a of an artificial Horse, which was capable of advancing seven or eight Leagues in a day upon a flat Field; and the Figure of a Man, an iron Statue, contrived by a Prisoner, which having gone out of the Prison, went thro' several windings and turnings, to present upon its Knees a Petition to the King of *Morocco* in his Palace, and return'd to the Prison^r. And is it not said that *Albert* the Great made a Head, which uttered some words? I don't warrant these Facts; but I have seen a Brass-horse, which by secret Springs turn'd about as Horses do in the managing.

If the Industry of Men makes Machines of so ingenious a Structure, what cannot infinite Wisdom do?

Eudox. Let us not limit Wisdom that is without Limits. But a thousand places of

^a Journ. des Sçav. 1680. p. 12.

^r *Ibid.* 1683. p. 301.

Scripture seem to ascribe some knowledge and passions to Animals. The Author of Nature has created us with a certain Bias, which leads us all to attribute those things to them, and which, perhaps, inwardly contradicts any one who should refuse His assent. They have Senses as well as we, and which bear some resemblance to ours. The impressions which we receive thro' our Senses, do not produce the motions of our Body without our Soul's being concerned in them. We do not feel those impressions in our Members, which of themselves transport our Bodies toward sensible Objects. We do not perceive our selves forced to use the power of our Soul in order to stay the impetuosity of the Body at the sight of the most exquisite dainties, even when we are pressed with hunger. Upon what Principles shall we say then, that the sensible impressions received into Animals thro' Organs which appear so like those of our Bodies, should of themselves transport their Bodies, without any Soul influencing them, in order to determine their motion?

Arist. We must then give reason to Animals?

Eudox. Faith teaches us that the Soul of Beasts is not a Spirit. If animals had reason, the language of Parrots, and the thirty words pronounced by the *German Dog*, mentioned by M. *Leibnitz*, would have nothing in them so surprizing. It would be more astonishing

nishing that Animals do not speak more to us, at least by Signs. Reason would teach them to know us, and to explain themselves better. We must always look upon Beasts as Beasts. They never had Reason. Therefore the different Species of Beasts have nowise improved themselves by time.

Arist. But, what is then the Soul of Beasts? Is it the most subtile of Bodies? Is it extracted from the bosom of Matter? Or, is it I know not what modification of the Body?

Eudox. Matter which in its natural State is only an extended and impenetrable Substance, being only susceptible of rest, motion and figure; cannot feel, know, desire, fear or suffer. Is it not more probable that the Soul of Beasts is a Substance, which is really neither Spirit nor Body? A third Species of Substance only capable of sensible passions and perceptions, or of sensations, but exquisite Sensations or Sentiments, which in practice are sometimes equivalent to reasonings, a Substance depending upon the Organs of the Body, useless without the Body; without reflections upon its perceptions, without deliberation, choice, liberty, or merit; and consequently destined to perish with the Body?

However that be; the Earth, Waters, human Bodies, Plants and Animals, are so many sources of Meteors, elevated above our heads. Let us therefore, *Aristus*, dispose our selves to carry our views a little higher.



CONVERSATION VII.

*Upon Meteors.**Eudox.*

WITHOUT doubt, *Aristus*, you will give us, in the first place, a just Idea of Meteors.

Arist. The Meteors are Phænomena, which are observed in the Atmosphere; as Exhalations, Vapours, Fogs, Evening Damps, Dew, White-frost, Mildew, the Winds, Clouds, Rain, Snow, Hail, Thunder, the *Aurora Borealis*, the divers Fires which Nature kindles from time to time, and the Rain-bow.

Eudox. What a pleasure is it to Philosophers, to contemplate this admirable variety of Phænomena, and discover the Means which Nature employs, in order to afford this spectacle to the Universe!

Arist. I take a particular pleasure in making some enquiry into the Thunder; and I shall communicate it to you, when you have informed me concerning the other Meteors.

Eudox.

Eudox. Some Letters, which I wrote, and of which I keep the original Copies, express my Sentiments on this head.

L E T T E R I.

Upon Vapours, Exhalations, &c.

YOU ask my opinion of the nature, causes, and elevation of Vapours and Exhalations, of the Damp, Dew, White-frost, Mists, Rime and Mildew; here it is:

1. Vapours are aqueous Particles, which come out of the bosom of the Waters, and flutter in the Air. Thus Vapours re-united by cold, compose sometimes those species of Smoak which wet, and which you see rise out of Wells, Rivers, Ponds, and the Sea; sometimes sensible drops of Water, such as one sees in Summer upon Marble, upon the internal surface of Vaults, and upon pewter Vessels full of fresh Wine.

As for Exhalations, they are particles which are exhaled from terrestrial Bodies. Thus Rain-waters composed of Vapours, and impregnated with Exhalations, deposite in the bottom of Reservoirs a sensible Earth, whose parts form the grosser Exhalations. Ordinary Exhalations consist of volatile, nitrous, or vitrioline Salts. The most subtle of Oils or sulphureous Spirits.

2. But

2. But what is it that causes and elevates Vapours and Exhalations *. The action of sub.

* It has been long observed, that in close and rainy weather, the Quicksilver does not rise so high, as when it is dry and clear; which has been thought by some to overthrow the whole Theory of the Weight of the Air; and indeed it is very difficult, to explain particularly the Causes of all the various and minute Changes of the Heavens; a great deal is owing to the Winds, which blow sometimes upwards, sometimes downwards, and sometimes sideways; a great deal to Vapours; a great deal to Steams rising out of the Earth; something must be ascribed to the alteration of the Heavens in the neighbouring Countries, and perhaps something to that *flux* and *reflux* which the Moon causes in the Air, which is much greater than that in the Sea, &c. To account for all which particularly and exactly, would be endless. However to propose something which may come pretty near the Truth; it is to be observed, that the *Air it self* is heavier than the *Vapours*, and fitted to support them, because its Particles are grosser, and arise from denser Bodies than the Particles of Vapours. In the first place therefore, this weight of the Air, in any particular Country, may be so changed by the Winds, that the Atmosphere may be condensed and made heavier, by bringing a greater Quantity of Air and heaping it together, viz. Whenever two Winds blow at the same time from contrary parts of the Heavens; or some of the Air may be carried or blown away by them, and thereby an opportunity given to the Atmosphere to unfold itself, the incumbent Weight being taken off, viz. as often as two Winds blow from the same Country to opposite parts of the Heavens; or whensoever any particular Wind is very strong; for it is found by experience, that an artificial strong Wind makes the Air lighter, and the Quicksilver in the Tube to fall very much. See *The Philosophical Transactions*, N^o 292.

Secondly, Cold and nitrous Particles of the Air itself, condensed by cold from the North, must condense the Atmosphere wherever it comes, and make it heavier.

Thirdly, Heavy and dry Exhalations make the Air heavy (in the same manner as the specific Gravity of any Menstruum is encreased, by dissolving Salts and Metals) and its *elastick Force*, as it is called, must thereby become so much the stronger.

Fourthly, When the Air by these and such like causes is become heavy, then it is more able to support the Vapours, which when they are entirely mixt with it, and swim about, and are every

subterraneous Fires and Heats, the Heat of the Sun, and Weight of the Air; and often the blowing of the Winds contribute to it. The action of subterraneous Fires or Hearts, agitates both the Waters and terrestrial Bodies, divides, comminutes and fills their Particles, or surrounds them with subtile Matter; makes their Volumes lighter than an equal Volume of Air; impels, bears up, and makes them ascend after the same manner as the Heat which penetrates the Bottom of an Alembic; makes the fine Particles of the Bodies which it encounters, to ascend in Vapours or Exhalations. Hence those who labour in Mines which are more than

every way dispersed in it, make the Sky serene and clear: But when the Air from contrary Causes, is made lighter, then is it unable to support the Vapours with which it is always filled, and so being put into some sort of violent agitation, they gather themselves into Clouds and Mists, and being formed into Drops, fall down.

From these Observations, it is very evident, that the same Causes which make the Air heavier, and more able to sustain the Quicksilver in the Tube, make the Heavens also clear and dry; and by the same Causes, by which the Air is made lighter, and less able to sustain the Quicksilver, are Showers and Rain produced also.

Hence it follows, First, that when the Air is lightest, and the Quicksilver falls lowest in the Tube, then the Clouds move very low and quick; and that the clear Air, which after Rain, appears between the thick Clouds, being discharged of its Vapours, seems most transparent and bright, and gives the best and easiest prospect of things at a distance.

Secondly, When the Air is more heavy, and the Quicksilver is raised higher in the Tube, then the Heavens are fair; but a little thicker, and not quite so blue, by reason of the Vapours which are every way equally dispersed about; and, as has been by many observed, it does not afford so good a Prospect of Things at a distance: and if there do appear any Clouds, they are very high

than three hundred Fathoms deep, where the Heat of the Sun scarcely penetrating some few feet below the Surface of the Earth, has no access, do nevertheless perceive Vapours and Exhalations, which sometimes colour the Flame of a Candle.

Fermentations caused by the Heat of the Sun in Waters and terrestrial Bodies, detach from them Vapours and Exhalations, and elevate them, as does the Action of subterraneous Fires and Heats. Wherefore Liquors exposed to the Sun, are considerably evaporated; and between the Tropics, where the Heat of the Sun is most violent, the Vapours are so abundant

high and move very slow; and when the Air is heaviest of all, the Earth is sometimes covered with very thick Clouds, which seem to consist of heavier sort of Exhalations, which the Air, at that time, is capable of sustaining, but which cannot swim in lighter Air.

Thirdly, Hence it is, that in our own Country, when the Cold is greatest, and the North and North-East Winds blow, the Quicksilver in the Tube is highest, because at that time two Winds blow together upon our Country from opposite parts of the Heavens: for in the *Atlantick Ocean*, at the same *Latitude* with us, the Wind blows almost always from the West. To which we may add, that the Air which is brought hither by the North Wind, comes condensed by the Cold.

Fourthly, In the most Northern Countries, there is greater variation of the height of the Quicksilver in the Tube, than in those Countries which are more South; because in those Countries, the Winds are stronger and more variable, and opposed by each other in a less Tract of Land; whence the Air is sometimes more heaped up and condensed, and sometimes carried away and lightened.

Lastly, Between the Tropicks, there is the least Variation of all, in the height of the Quicksilver in the Tube, because there the Wind is for the most part very gentle, and blows the same way. See *Philos. Transact.* N^o. 181.

stant in the day time, that they fall again in Rain the whole night ; which temperates the excessive Heat, and renders those Countries habitable, notwithstanding the burning Heat of the Sun.

When the Exhalations and Vapours are detach'd by the Fermentations, and enclosed or filled with subtile Matter, and are lighter in bulk, than an equal bulk of Air, the Air which serves it self to detach them by its continual agitation, bears them up by the Action of its Gravity ; almost as Water makes a Football full of Air ascend by the excess of its Weight.

Finally, The Winds, which ruffle the Waters and dry the Earth, ought to carry off Vapours and Exhalations ; and when, being reflected, they strike against the Surface of the Exhalations or Vapours, ought they not to contribute to their Elevation ?

3. Vapours and Exhalations, which rise up and hover about on all sides, produce after an imperceptible manner effects equally perceptible and surprizing. Often by reason of the Corpuscles, which they carry off from all parts, they are the original of Diseases. Oftentimes penetrating, like so many Wedges, Ropes and Wood, they straiten the Ropes and swell the Wood ; so that the straitening of the Cords, or swelling of the Wood, is a Species of Hydrometer, that is, an Instrument fit for measuring the humidity of the Air.

There

There is also nothing more wanting than the imperceptible action of Vapours and Exhalations to cleave the hardest Rocks. What method is used to detach Mill-stones from Rocks, which have been cut out in form of a Cylinder? They make a number of Holes round about those Rocks. They put into those Holes pegs of Wood dried in an Oven. These Pegs are disposed all round, according to the largeness of the Mill-stones. In wet Seasons, the Vapours and Exhalations insinuate themselves, like so many small imperceptible Wedges, into those more massy kind of Wedges, inflate, and swell them; being made larger, and forced to possess a larger Space, they cleave the Rocks, and detach the Mill-stones.

4. Should a mixture of Vapours, and especially of Exhalations, elevated by the Heat of the Day, happen to cool again, to condensate, and at last to fall down by its proper Weight after Sun-set, this is the Damp. There is no Damp in Winter, because then the Heat is not strong enough to elevate the Exhalations, which are terrestrial, grosser and heavier than Vapours. The Damp falls in the Spring, Summer and Autumn; and if it falls later in Summer than in the other Seasons, the Reason is, because in Summer the Cold necessary for condensing, and rendring heavy the Exhalations, is later. These Exhalations contain many sharp and corrosive Corpuscles, especially in places where there are many Minerals. Wherefore

fore the Damp is often noxious, especially to those whose Pores are more open, and afford a freer access to the Action of the Corpuscles. Hence Defluxions, Tooth-aches, Hemorrhages, Head-aches, Watchings, Difficulties of Breathing, Oppressions; the sad Consequences of an agreeable Walk.

5. The Morning Dew, which contains fewer Exhalations, and consequently is lighter than the Evening Damp, comes naturally after it. It consists principally of Vapours, which the Heat of the Day has not elevated very high, being condensed by the Cool of the Night, and becoming perceptible by their being united together, toward the Morning, upon the Leaves and Flowers; where you see them suspended, transparent and sparkling, as a Species of small Diamonds, wherewith the Poets say *Aurora* takes pleasure to bespangle the Meadows. Thus dry places, which afford no Vapours, are destitute of these poetical Riches. The Morning Dew requires a calm Air, and clear Sky; the Wind dissipates it, and Clouds absorb it. It is more frequent and abundant in Spring and Autumn, than in Winter and Summer; because in Winter the Heat attracts fewer Vapours, and in Summer the Heat volatilizes them, raises them too high, and in some measure consumes them.

6. Do the small Drops, which make the Morning-Dew, happen to freeze by the Coldness of the Air? This is Frost.

7. The

7. The Mists are thick Collections of grosser Vapours and Exhalations, which their Weight, or the Cold that condenses them, hinders from rising much above the Surface of the Earth, which they wet. The Cold, which unites the Vapours and Exhalations, renders the Mists perceptible, as it makes the Breath and Sweat of Horses perceptible in Winter, by re-uniting the Particles, which the Heat of Summer dissipates, and does not suffer to be perceived.

Ordinarily one sees Mists arise out of Rivers, Valleys, and Marshes; because those places have more aqueous Parts, and the terrestrial Parts therein being less united, are detached and elevated more easily in Exhalations. Exhalations and Vapours that come out of muddy and marshy places, ought sometimes to be impregnated with stinking Corpuscles. Thus Mists, sometimes, exhale a disagreeable Odour.

8. Are the Mists charged with nitrous or sulphurous Corpuscles, capable of tearing the Fibres of Plants, Ears of Corn, or Fruit yet tender? If these Corpuscles happen to fall in small Rain, it is Mildew. Mildew is attach'd to Plants; the Points of its nitrous and sulphurous Corpuscles sink into and disorder the Fibres, and hinder the Motion of the Juices; the Plants and Ears of Corn are dried up and fade away for want of Nourishment, and the Reaper at once perceives all his pleasing hopes blasted.

9. When the Rays of the Sun pierce the Mist, the Heat rarefies it, the Rarefaction renders it lighter. Being lighter, it is elevated in a Cloud, or dissipated. Sometimes the lighter Parts being separated from the grosser by the Heat, are lost in the Atmosphere, while the grosser Parts fall down again upon one another, or near one another; and by being united, compose a Species of long and white Thread, which floats at the pleasure of the Air, and to which they give the agreeable Name of the Hair of *Venus*.

Here, Sir, is my Opinion of the Vapours, Exhalations, both Evening and Morning Dews, white Frosts, Mists and Mildew.

Arist. Vapours are, you say, Particles of Water; and Exhalations are terrestrial Particles, elevated in the Air. The subterraneous Heats, the Heat of the Sun, the subtile Matter which contributes to the lightness of the Volume of which it makes a Part, the gravity of the Air, and the blowing of the reflected Winds; are so many Causes which may concur to the elevation of the Vapours and Exhalations. Do some imperceptible Exhalations, mixt with some Vapours, fall about Evening? It is the Evening Dew. Do imperceptible Vapours fall in the Morning, which make sensible drops by being united upon Plants, Leaves, and Flowers? It is the Morning Dew. Does the Cold of the Air lightly freeze the Dew? It is white Frost. In a word,

a thick Collection of Vapours and Exhalations that have risen out of moist places, and are diffused in the Air, but detain'd near the Surface of the Earth by their Weight, or by the Cold, is what they call a Mist. Certain nitrous and sulphurous Salts, which the Mist lets fall upon Plants, make the Mildew; and certain gross Exhalations by being united, make this Species of white Thread, which one sees sometimes attach'd to Plants, and sometimes flying at the pleasure of the Wind. These are Phænomena, *Eudoxus*, which your first Philosophical Letter explains after such a manner, as to give me a Taste for the second.

Eudox. Here it is.

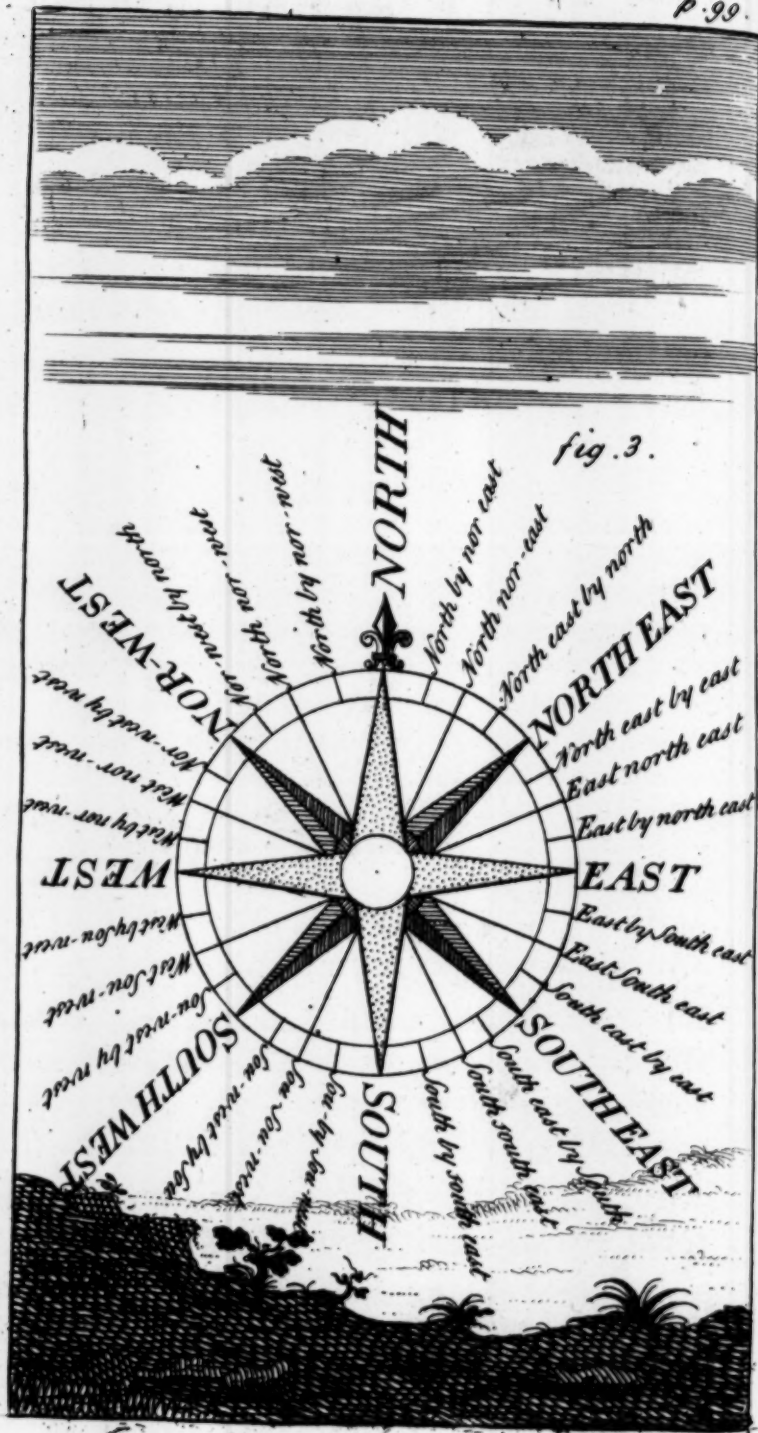
LETTER II.

Upon the Winds.

WHAT is Wind? How many Winds do they reckon? What, is in short, the History of the Winds? What are the general Causes of Winds? Whence proceeds the different direction, the diversity of Winds? From what arise the different qualities of Winds? These are so many Questions, which you propose to me: I shall answer them in the same Order, and in few Words.

1st Question. *What is the Wind?* It is a sensible Agitation of the Air, a sensible Translation of the Air from one place to another.
The





The Fan, which the hand agitates, only sensibly agitates the Air; and it produces a small cool Wind, a small Zephyr, which conveys coolness.

2d Question. *How many Winds do they count?* One may count as many as there are Points in the Horizon. Nevertheless, they only count thirty two; because this number is sufficient for determining those which are useful in Navigation. Here are their Names and Situation in the following Figure, Fig. 3.

North, South, East, West; North-East, North-West, South-East, South-West; North-Nor-East, North-Nor-West; South-South-East, South-South-West; East-Nor-East, East-South-East, West-Nor-West, West-South-West, North by North-East, North-East by North, North-East by East, East by North-East, &c. Names more useful than musical.

The four first, namely, *North, South, East, West*, are called *Cardinal*; because they proceed from the Cardinal Points of the Horizon.

The four following, namely, *North-East, North-West, South-East, South-West*, are called *Collateral*; because they are between the first. Every one of the collateral Winds is in the middle of two cardinal Winds, having their Name composed of the two Winds, in the midst of which they are. Is it between *North* and *East*? It is called *North-East*. Is it between *North* and *West*?

It is call'd *North-West*. Between *South* and *East*, *South-East*? Between *South* and *West*, *South-West*.

The eight Winds following, every one of which is situated in the middle of a cardinal Wind and a collateral one, have a Name composed of the Names of both. Is the Wind precisely in the middle of the *North* and *North-East*? They call it *North-Nor-East*. Is it in the middle of the *North* and *Nor-West*? They call it *North-Nor-West*, &c.

The last Sixteen take their Names, both from a cardinal Wind and from a collateral, to which they add the word *by*. The Name of every one begins with that of the Wind near which it is; and ends by the Name of the Wind, which is farthest distant from it. For example, the Wind which is nearest to the *North*, passing toward the *North-West*, is called *North-by-Nor-West*; because it is the fourth, counting from the *North-West* to the *North*, &c.

3^d Question. *What is in a few words the History of the Winds?* Between the two Tropics, a continual Wind prevails, which blows incessantly from East to West. There are other remarkable Winds between the Tropics, and such as they call Trade-winds. The Trade-winds are the Winds of the *North-East*, and *South-East*, which are perceived between the Tropics. Without the Tropics, from the 23^d Degree of Latitude to 40, they observe a West-wind pretty constant; the East has

has its Trade-winds, which are periodical Winds, or which blow regularly from divers parts, according to the diversity of the Seasons. Such are those Winds which reign in the Seas of *India*, and of *Arabia*, and which blow for the space of six months from one side of the Horizon, and during other six Months from the other side. There are the Trade-winds of Winter, and others of Summer; they call those Winter Trade-winds, which blow for about six Months from between the North and East. They call those Summer Trade-winds, which proceed for six Months from between the South and West.

There are few regular and periodical Winds, in comparison of those which are variable. Variable Winds are those which blow sometimes, and at other times blow not at all; which blow sometimes from one Corner, sometimes from another. The Winds, which are felt in these Countries, are almost all variable Winds. The Hurricanes are Winds, which carry Desolation into the Countries which they pass over. The East Wind is ordinarily dry with respect to us; the West Wind rainy; the South Wind hot; and the North Wind cold. Finally, the Winds are sometimes hurtful, sometimes salutary.

The fourth Question. *What are the general Causes of Winds?* The violent Eruption of Vapours and Exhalations, caused by subterraneous Fermentations; the Rarefaction

of the Air by subterraneous Fermentations, or by the Heat of the Sun; and the Fall of Clouds.

The violent Eruption of Vapours and Exhalations. We cannot doubt the Winds issuing out of the Earth and Waters; they come from Caverns, Gulfs, and Abysses. There arises one out of the Mountain of *Malignon* in *Provence*; which extends no farther than the very Brow of the Mountain. There arises another in *Dauphiny* near to *Nilfonce*, which reaches a very short way. Sometimes one sees in a full Calm the Waters of the Sea ruffled suddenly round a Ship before the Sails are inflated; the Waves formed into Furrows, and driving one another toward some particular Side; then you perceive the blowing of the Wind.

Now, how are these kind of Winds formed? In order to comprehend this, one may compare the subterraneous Cavities to the Cavity of an *Æolipyle**; the subterraneous Heats to those of Fire, upon which they place the *Æolipyle*; and the Chinks of the Earth, the Caves, and Vents, thro' which the Vapours can get off, to the Hole of the *Æolipyle*. Place an *Æolipyle* upon the Fire, containing in it some Water; in a short time the Water is evaporated; the Vapours issue out rapidly, being forced to pass in a little time from a

* Vol. I. V. Convers.

large Space into a smaller one, and protrude the Air; this rapid Impression makes a sort of Wind to be felt. After the same manner the subterraneous Fermentations and Heats, cause great Collections of Vapours and Exhalations to issue out hastily from certain parts of the Earth and Waters, as so many *Æolipyles*. These Exhalations and Vapours being thrown out violently, drive the Air according to the Direction which they have received in issuing out of the Earth or Waters. The Air being violently driven, communicates its Motion to the Air before it. Hence, this sensible Current of the Air, in which the Wind consists; hence this Flux, this successive flowing of the Air, which seems to imitate the Motion of the Waves, and makes the Puffs. In short, sometimes when the Weather is fair, and the Air calm, upon the *Garonne* near *Bordeaux*, in the Lake of *Geneva*, and in the Sea, one sees places bubble up suddenly, and the Bubbles followed with impetuous Winds, and furious Tempests; and *Fienus* says, that walking one day upon the Sea-shore, he saw a Mist rise out of the Waters like a sort of Smoak, and that this Mist was followed with a most terrible Storm. And what is it that produces the Typhons, those Winds so dreadful in the *Indian* Seas? The subterraneous Vapours and Exhalations; for before the Typhons, the Waters of the Sea grow warm,

the scent of Sulphur is observed; and the Sun is darkned^f.

The Rarefaction of the Air. The Air being rarefied, whether by subterraneous Fermentations, or by the Heat of the Sun, cannot possess a larger Space, without driving away the adjacent Air; the Air being driven, flows towards the place where it meets with least Resistance; and if this flowing is sensible, it makes a Wind. Thus the Air of the Chimney, being rarefied by the Heat, produces in the Air, surrounding it a small Wind, whose Motion is accelerated, and makes itself heard in the Interstices of the Door or Windows of the Room where the Fire is made. Why is the Sun-rising in Summer-time pretty often attended with a small Wind? Probably it is the Effect of the Rarefaction of the Air caused by the Heat of the Sun, the Impression of which makes itself felt even by us. After this, need we be astonished, if a Wind reigns between the Tropics, which blows incessantly from the East toward the West? The Rarefaction which the Heat of the Sun causes in the Air, Vapours, and Exhalations, with a Direction from East to West, may produce this Phænomenon. Thus Mariners observe, that the Wind is stronger in the Day than in the Night^g.

^f Mem. de l'Acad. 1687. p. 261.

^g Abregé de Gass. T. 5. p. 188.

The Fall of the Clouds. The Fall of the Clouds being dissolved by the Heat of the Air, and becoming more weighty, strongly agitates the inferior Air ; and this violent Agitation is a Wind, which lasts for a short while, but is impetuous. This sort of Winds are ordinarily followed with Rain ; because the Clouds whose fall produces them, are resolved into Drops in their falling. Sometimes the Mariners perceive a Cloud over them, which at first appears very small, because it is much elevated, but seems to enlarge gradually, because it descends and approaches, and whose fall upon the Sea is accompanied with Rain, Storm, and Tempest.

In a word, the height, largeness, and situation of Mountains, sometimes straitens the Passage of Vapours and Air agitated, and by that means causes an acceleration in their Motion. This Motion becomes sensible ; and this is a real Wind. Thus, when Vessels pass along the Coasts of *Genoa*, where there are high Mountains, and they are over-against some Valley, whose direction faces the Sea, there is felt a considerable Wind, which comes from the Land^u.

The fifth Question. *Whence proceeds the different direction or diversity of Winds?* From the different Situation of the Causes or Places whence the Impetuosity of the Air proceeds, and of those which reflect it. Bodies

^u Regis. T. 2. p. 180.

which

which move from a place, follow the direction which they received at first, until some obstacle give them a new direction. Is the Neck of an *Æolipyle* toward the South? A Wind issues out of it, which proceeds from the North Point. Does this Neck lie Northward? A Wind issues out of it from the South Point. After the same manner the Direction of a Wind, which issues out of the Earth or Waters, answers to the Direction of the Vent thro' which it comes forth. In *Provence* there is a Mountain pierced thro' in the North and South part; from these two opposite Apertures proceed two opposite Winds; from the first a Wind, which diffuses itself from the South toward the North; from the other a Wind, which blows from the North toward the South. According to the same Principle, does there happen in the Air some considerable Rarefaction on the South part? The lateral Air being impell'd by the force of the rarefied Air, flows towards the North where the resistance is least; and this is a South Wind. Does the Rarefaction happen on the North side? The Air being impell'd, flows towards the South; and this is a North Wind. Does a Wind encounter Heights, Mountains, and Clouds? It is reflected, making an Angle of Reflection almost equal to the Angle of Incidence. Hence a South-wind becomes a North-wind; a North-wind becomes a South-wind, &c. If Winds proceeding from divers parts hap-

happen to encounter one another, the weaker ought to give place to the direction of the stronger; since the greater Force prevails. Suppose a North or South Wind encounter a feebler Wind from West or East, the feebler whirls about, and is absorbed; and this is a Species of Whirlwind.

We may now, I think, easily comprehend what concerns the East Wind, which reigns between the Tropics. This Wind seems not to be produced by the daily Motion of the Earth upon its Axis from the West toward the East. For they find Calms in the *Atlantick* Sea near the Equator, and periodical Winds from the West under the Equator itself. Whence then proceeds the East-wind, which reigns between the Tropics? In proportion as the Sun advances from East to West, he dilates the inferior Air. The dilated Air propels the preceding Air. The thick and gross Air, which follows the dilated Air, mixes itself rapidly with it, in proportion as the Sun retires. Hence the East-wind, which brings home our Vessels loaden with the Riches of the East.

With the same ease one may comprehend the Trade-winds, the constant West Wind between 23 and 40 Degrees of North Latitude, the Monsons in the *Indies*, the variable Winds, and Hurricanes.

1. The Trade-winds, or the Winds of the North-East and South-East, which blow between the Tropics, depend upon the different
Rare-

Rarefaction of the Air caused by the different Situation of the Sun, which produces greater Rarefactions under the Tropics than under the Equator; because toward the Tropics he is longer above the Horizon. The Trade-winds being reflected obliquely by the mountainous Coasts of *America*, make the constancy of the West Wind, which blows without the Tropics.

2. The Monsons in the *Indies* depend, as well as the other Trade-winds, upon the different situation of the Sun, which rarefies the Air more, elevates the Vapours and Exhalations more, when he is more perpendicularly over a Country, and gives them different Directions, according as he is differently situated. 4. Irregular Fermentations produce the variable Winds. 5. Should the Action of some subterraneous Fire, or of some violent Fermentation, shoot out a great Quantity of Vapours and Exhalations obliquely into the Air; should a thick Cloud happen to fall obliquely from on high; the Air charged with Exhalations and Vapours, and impell'd forward by an extraordinary force, spreads itself, flows rapidly, following the Direction which it hath received, agitates and over-turns whatever it encounters, Trees, Buildings, and Houses; and this is an Hurricane.

Water-Spouts are probably caused, like the most part of Hurricanes, by subterraneous Fermentations. These Water-Spouts are Pillars of Smoak, which arise out of the Sea.

At

At first one sees the Water bubble up. Then a black Smoak is thrown out and elevated, with a hollow Noise, like that of a Torrent. If a Vessel encounter it, the violence of the obscure Column bursts the Sails. Sometimes it bears up the Vessel itself: the Vessel being born up, falls down again, quickly by its weight; and its Motion being accelerated in the Fall, buries it in the Waters, while the Column continues to elevate itself by whirling about rapidly, and is lost in the Clouds. When the Mariners perceive the Danger, they shoot off some Guns charged with Bars of Iron, in order to drive off the dreadful Column to some distance by the impulsion of the Air, or to cut and dissipate it, by dispersing the Water which composes it *.

6th Question. *Why are Winds dry or wet, hot or cold, hurtful or salutary? Whence proceed the different qualities of Winds?* The greatest part of them proceed from divers Corpuscles, which they carry off with them, according to the divers Regions, out of which they arise, or thro' which they pass. Are the Winds but little charged with Vapours? They are dry. Hence East Winds, which pass thro' a great tract of Land, and but little Sea, are ordinarily dry. Do Winds bear along with them plenty of Vapours? They are wet. Hence West Winds, which pass thro' a length of Sea, are ordinarily rainy. Do Winds come

* Journ. des Scav. 1682. p. 133. 27 Avril, & p. 205. 29 Juin.
from

from hot Countrys? They are generally hot; because they bring along with them Vapours, Exhalations, or Particles of Air agitated with that universal Motion, which makes heat. Hence South Winds are ordinarily hot. The cold of the severe Winter in 1709, appear'd to be for several Days the effect of a South Wind; but the Mountains which are on the South of *Paris* were at that time covered with Snow, and this South Wind could be nothing else but a reflux of a North Wind, which had preceded [†]. Do Winds proceed from cold Countries? They are commonly cold; because they bring along with them Particles which have only a direct Motion, or which contain in them plenty of Salts, Nitre and Icicles, which certainly contributes to render the Winds cold. In short, put some small Icicles, at the vent of a pair of Bellows, a colder Wind issues out. Hence the North Wind is ordinarily cold. Finally, Winds are hurtful or salutary, according as the Corpuscles with which they are charged in different Parts, are hurtful or salutary. Here is, Sir, my Sentiment concerning the Winds.

Arist. But when a South Wind has blown, why is it not always immediately followed with a North Wind? The Air, I think, ought to flow back, there being no *vacuum*; do not the Elasticity and *Æquilibrium* of the Air require it?

[†] Hist. de l'Acad. 1709. p. 9.

Eudox.

Conv. VII. Of METEORS. III

Eudox. The Air ought to flow back, but it may do so below our Hemisphere, or thro' the superior region of the Air; or else make a circuit, and return through some place which allows it a freer space for extending itself.

Arist. Do you believe, *Eudoxus*, that the Winds explained after this manner produce the Currents of the Sea?

Eudox. The Currents of the Sea, which are as it were Species of Rivers in the middle of the Sea, seem to me to depend upon subterraneous Rivers in the bottom of the Sea, interrupted by Rocks, Islands and Winds. There are perpetual Currents; some are regular, or such as without being perpetual, are formed at certain Seasons, and in certain Places. Some of them are periodical, or such as carry the Waters sometimes to one side, sometimes to another; and some are variable. Perpetual Currents probably proceed from certain subterraneous Rivers, which are emptied into the Sea. Other Currents proceed from this, that the Waters being driven by the Winds, are reflected by Islands, Lands and Rocks, or are more shut up in certain places than others, because there are Islands or Rocks parallel, which straiten the passage of the Waters, and constrain them to accelerate their Motion. The regular Winds produce periodical Currents; and variable Winds, variable Currents.

Arist.

Arist. Here is, I think, in few words your Sentiment of the Winds. 1. Wind is in general a sensible Translation of the Air from one place into another. 2. They reckon up 32 Winds; four Cardinal, four Collateral, &c. 3. Subterraneous Fermentations, the Heat of the Sun, the Eruption of Vapours and Exhalations, the Rarefaction of the Air, and the Fall of Clouds are the Origin of Winds. 4. The different Direction of Winds proceeds from the different Situation of the Parts whence they come, or by which they are reflected. 5. The Winds have different qualities, according to the Corpuscles, and the Agitation of those Corpuscles which they carry along with them. 6. The East Wind, which blows continually between the Tropics, proceeds from the excessive Rarefaction of the Air between the Tropics; the Trade-winds from the inequality of Rarefaction in the Air under the Tropics and Equator; the constancy of the West Wind in certain Countries, from the Reflection of the Trade-winds, caused by the Mountains of *America*; the different Monsons in the *Indies*, from the different situation of the Land of *Asia*, and of the Sun; and the Hurricanes, from the violent fall of some Cloud, or from subterraneous Fires. 7. Irregular Fermentations produce variable Winds. Finally, upon variable Winds depend variable Currents; upon periodical Winds, periodical Currents; and upon regular Winds, regular Currents.

I easily enter, *Eudoxus*, into your Sentiment; and the Clouds, which I see carried at the pleasure of the Winds, double my earnestness of knowing what you have written upon Clouds, Snow, Rain, and Hail.

L E T T E R III.

Concerning the Clouds, Snow, Rain and Hail.

Eudox. **S**IR, After one knows what concerns Vapours, Exhalations, Mists, and Winds, it is easy to comprehend what relates to Clouds, Snow, Rain and Hail.

Clouds are a collection of Vapours and Exhalations suspended in the middle Region of the Air; and whose thickness obscures the Heaven. In short, Clouds differ but little from Mists, only in this, that they are lighter and more elevated. Thus, those who ascend the *Alps* and *Pyrenees*, or high Mountains of *Hungary*, when they arrive at the Clouds, imagine to themselves that they are entering into a sort of Mist.

Clouds are formed by the rencounter of Exhalations and Vapours, by cold, and by the action of Winds. The Vapours and Exhalations which happen to touch one another, are hooked together in the shock, lose their Motion, and rest near one another; the Cold condenses them in the Atmosphere, as it

condenses them upon the interiour Surface of the Head of an Alembick ; and the Action of the Winds re-unites them. All these Causes concur to produce those Masses extended over our heads, which shutting up the Passage of the Sun-beams, withhold the Heaven from our Eyes.

That which makes the Exhalations and Vapours to ascend, as Fermentations, the Gravity of the Air, and the blowing of the Winds, elevates also the Clouds. The Clouds are more or less elevated in proportion to their Gravity, the Gravity of the Air, and the Strength and Situation of the Winds, which blow from below upward. Wherefore, during Summer, the Clouds are ordinarily farther distant from the Earth, because containing more igneous Particles, they are more rarefied and lighter.

But what is it that holds the Clouds suspended in the Air ? The igneous or subtile Matter, which surrounds the Exhalations and Vapours, or which is contained in them, the Air, the Winds which come from the Earth, and the Expansion it self of the Clouds, all these contribute to it. The igneous or subtile Matter, renders the Volume of the Cloud lighter, and in a better condition of being sustain'd by the Weight of the Air. The Winds which blow from below upward, sustain it. The Expansion of the Cloud gives it a large Surface in regard of its Mass, and is the Cause why the
infe-

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inferiour Air cannot give place, unless a large Volume of Air give place at the same time. This large Volume of Air cannot give place at the same time, without being forced to go with a very great Velocity in order to reach the Extremities of the Cloud. Now the excess of Gravity, which may be in the Cloud, is not sufficient to communicate this excess of Velocity to the inferiour Air. Hence the inferiour Air resists, and sustains the Cloud for the same reason, as Water, which does not sustain a golden Ball, sustains the same quantity of Gold extended into a very thin Leaf. The Resistance of a Body, answers to the Velocity necessary for its yielding.

Finally, Clouds are more or less obscure, in proportion as they contain more or fewer Exhalations and Vapours; because then the Light finds more or fewer Passages *. According to the divers Changes which the Clouds cause in the Light, they have different Colours; they are blue, white, red. If they are of unequal Weight, they are elevated above one another. Are the Vapours and Exhalations, which compose the Clouds, united together in divers parts? Are they of unequal Gravity, and differently agitated by the Winds? You see Clouds of different shapes. Sometimes the Heaven appears bestrewed with sorts of Fleeces; sometimes they are as it were Ridges of Mountains and Rocks, which bound the Horizon, and proceed by degrees to lose them-

* See Notes Conversat. XXII. Vol. II.

selves in a red or blue Heaven, and make Prospects, admirable Landskips, and Points of View inimitable by the Art of the Painter.

Should a frozen Cloud happen to be dissolved by its own proper Weight, or by the Impression of the Winds? It falls down in Flakes, which are composed of small globules of frozen Vapours, and fastened together by small Threads of Exhalations; and this is Snow. Snow consists in Flakes, which are a texture of small globules of frozen Vapours; such almost as one sees in Hoar-frosts, and fastened by very minute Threads of ramous Exhalations.

Snow is about five or six times lighter than Water, since being melted it is ordinarily reduced to a fifth or sixth part of the Height which it had*: Because the Interstices of the Globules, which compose the Snow, are full of Air, and the Bonds which attach them are very minute. They are, I say, very minute, since cold Water dissolves Snow. Snow is formed in a more elevated Region than that where Rain is formed: for Rain melts Snow, and one sees the top of high Mountains covered with Snows, which Rain does not dissolve. Commonly when Snow is ready to fall, and when it falls, the Cold diminishes. Probably the Cloud, which bears Snow, drives back the Exhalations which come from the Earth, and the Exhalations by that means

* Hist. del'Acad. 1711. p. 16.

acquire this universal Motion, which makes Heat. Finally, Snow contributes to the Fecundity of the Earth ; because it retains Exhalations, and brings along with it Spirits of Nitre, which being joined with the Exhalations, nourish and cherish the Plants.

If the Cloud is not frozen, or if it is melted by the Heat of the Earth or Sun, and distils in small Drops ; the small Drops are re-united in their Fall, become sensible ; and the sensible Drops make Rain *. Rain consists in the perceptible Drops which fall from the Cloud. The higher they fall, the grosser they are ; because in their fall they are re-united in greater number. Thus ordinarily in Summer, the Drops are larger than in Winter. Generally the Months of *June*, *July* and *August*, alone furnish as much Rain as all the other Months together^a, because the Heats of *June*, *July* and *August* elevate many more Vapours and Exhalations.

Would you have some certain Presages of Rain ? The Stars, Animals, and Barometer will furnish you. When the Light of the Moon or Sun is pale, the Stars sparkle, the Doors make a greater noise than usual, the Ants retire, and Swallows fly near the Earth, or the Barometer is low ; you may be afraid

* The most effectual Cause of Rain is the weakening of the Elasticity of the Air. See Notes, p.

^a Hist. de l'Acad. 1696. p. 406.

of Rain, the Air is impregnated with gross Exhalations and Vapours. In short, the gross Vapours and Exhalations usually diffuse a certain Paleness over the Sun and Moon, and render the Light of the Stars more twinkling, by virtue of their interrupting the Rays. They swell the Wood, fill up the Interstices. Hence, the Doors are opened with greater difficulty, and make more noise. The Ants retire, because the least Moisture renders their way almost impracticable. The Swallows graze upon the Earth probably in order to lay hold on the little Insects, which the Humidity makes to descend. Are not the Prognostics of the Barometer the most certain *?

Lastly, When Rain, or Snow almost melted, falling from on high, encounters in the Atmosphere with a cold Wind, or some place full of Salts, Nitre, Saltpeter, it freezes†, and this is Hail. Hail is only a Species of frozen Rain. In its fall it may encrease in bulk by virtue of its encountering with Vapours, which attach themselves to it, and in their being attach'd are turned into Ice. But, why falls there less Hail in Winter than Summer? Because in Winter, the Clouds not rising so high above the Horizon, the Snow falls before

* *Conversat.* XXII. Vol. I.

† As Water in a Vessel in the Summer-time is immediately turned into Ice, by externally applying Salt and Snow. See *Philos. Transact.* N^o. 231.

it is melted, or the Rain before it is turned into Ice. *I am, &c.*

This is my Judgment concerning aqueous Meteors; you will favour me with yours, *Aristus*, in another Conversation, concerning igneous Meteors.





CONVERSATION VIII.

*Upon Thunder.**Eudox.*

A M impatient, *Aristus*, to hear you discourse of Thunder. This is a Subject whose Name alone spreads Terror, but which will have nothing in it but Pleasure for me, while I hear you discourse of it like a Philosopher.

Arist. When one knows, *Eudoxus*, what you have told me concerning Fermentations, Exhalations, Winds and Clouds, it is easy to speak of Thunder as a Philosopher. Sometimes they distinguish the Thunder from the Thunderbolt, and they take Thunder for the Noise alone. Sometimes they confound the Thunder and Thunderbolt, and all Men seem so to do, when they say that the Thunder is fallen. For my part, I confound the Thunderbolt and Thunder; and I distinguish the Lightning and the Noise from the Thunder and Thunderbolt.

This

This being granted; What is Thunder*? Thunder is only a mixture of sulphurous, bituminous and saline Exhalations, enflamed in some Cloud. For, 1. Thunder is an inflammable Matter, imperceptibly elevated from the Bosom of the Earth into an upper Region, where it is enwrapt in some gloomy Cloud; which perfectly agrees with such Exhalations. 2. Thunder is inflam'd as of itself. Ought not a Mixture of those Exhalations to ferment and be inflamed after that fashion? We see in chymical Operations, an acid Spirit, with the essential Oil of an Aromatic Plant; for example, the Spirit of Nitre, with Oil of Cloves, two cold Liquids, to be inflamed at once as of themselves. 3. Thunders are so much the more frequent in a Country, the more Exhalations of this nature the Earth therein furnishes. 4. In places, where Thunder is fallen, they commonly perceive a scent of Sulphur and Bitumen; and would the Flame of the Thunder be so violent, if it did not contain volatile, nitrous, sulphurous, and vitrioline Salts, or others fit for shooting out on all sides? Lastly, One always conceives Thunder or the Thunderbolt, as a Fire contained in a Cloud, or darted into the Air from the Bosom of a Cloud.

Horace probably had a mind to droll like a merry Philosopher, when he said that they had seen *Jupiter* with the Thunderbolt in

* See Notes Conversat. III. Vol. II.

his hand, in a calm and clear Sky. Sometimes one sees the Lightnings, and hears the Thunder roar, in fair weather; but the Cloud, which bears the Thunder, is hid under the Horizon. The Exhalation which is not shut up in a Cloud, would be dissipated in the Inflammation without any crack, almost like Powder kindled in an open space. Therefore Thunder is a mixture of sulphurous, bituminous and saline Exhalations, inflamed in certain Clouds.

Eudox. Let us see deliberately, *Aristus*, how the Thunderbolt * ought to be formed according to your Principles, to be kindled, to produce Lightnings, and this terrible noise which follows them, to dart itself into the Air, to flutter about at the pleasure of the Winds, to strike the tops of Mountains, to cleave or eradicate Trees, to throw down Edifices, to melt Metals, to spare the tenderest Bodies, to destroy more solid ones, and to affect, if I may say so, to glance upon them sometimes without hurting them, &c. I shall only present you with the Thunderbolt, and the Species of Miracles, which it operates in Nature; you will discover to me the secret Causes and Springs. In the first place, in time of heat the Thunderbolt is formed in the Cloud.

* No such thing in Nature: the Mischief occasioned by Lightning, is to be attributed to its force being collected together.

Arist.

Arist. The Heat agitating terrestrial Bodies, the Bodies of Animals, and Minerals, detaches from them sulphurous, bituminous, nitrous, vitrioline Exhalations, &c. These Exhalations being detached by the heat, and born up by the weight of the Air, and the blowing of the Winds, are elevated into a colder Region, lose of their motion, are re-united and condensed in the Clouds; and this is the matter of the Thunderbolt or Thunder. Thus, as we have already observed, in hot Countries, and where the Sulphur, Bitumen, Nitre, Salt-petre, and Vitriol are in greater quantity, Thunder is much more frequent.

Eudox. At once the matter of the Thunder is enflamed, as of it self, in a cold Cloud.

Arist. The Shock of the Clouds kindles it, the Action of the Winds, the Heat of the Sun, or rather the Mixture of heterogeneous Spirits. There is nothing that takes fire more easily than Sulphur, and Bitumen, which burns even in Water. These oily Bodies are full of subtile and fine matter, continually agitated with rapidity. Some farther degrees of agitation still, and all their Particles, have this universal Motion, which makes the Flame. The shock of the Clouds, and the blowing of the Winds, are capable of adding these degrees of Agitation; and why may not the heat of the Sun, direct or reflected, do the same? We know that a moderate heat
inflamm

inflames the *Pulvis fulminans*. Likewise nothing more is required than a certain mixture of Exhalations, to cause an inflammation without the help of a foreign Fire; since a mixture of citrine Aqua-fortis, with the essential Oil of an aromatic Plant, takes fire of it self. And M. *Lemery*, of the Royal Academy of Sciences, having hid in the Earth about 50 pounds of a Mixture composed of equal parts of Sulphur and Filings of Iron, tempered with Water; after 8 or 9 hours the Earth vomited out Flames ^b.

Eudox. The moment of the Inflammation, the Lightnings are darted out of the Cloud.

Arist. The sudden and transitory Inflammation of the Exhalation, produces in the etherial matter, which surrounds it, and which it agitates, sudden and momentary Flames, which strike the Eyes briskly; and these are Lightnings.

Eudox. But if it is an inflamed Exhalation, which produces Lightnings, the same Exhalation must be inflamed several times, in order to produce that great number of Lightnings, which we often see issue out of a Cloud. Now can the same Exhalation be inflamed several times? A mixture of Liquors once inflamed in the Laboratory of our Chymists, is never kindled again.

Arist. A mixture of Liquors once inflamed in our Chymical Operations, is inflamed no

^b Hist. de l'Acad. 1700. p. 574. Mem. p. 102, 103.

more;

more ; why ? After the Materials, of which it is composed, are once inflamed, and consequently become very rare and light, the inferior Air more weighty than they compresses them, and elevates them into a superior Region, where they are lost to us. But are the same Materials elevated in Exhalations from the bosom of the Earth, as far as this upper Region ? The Cold re-unites them, and after this re-union, they do not remain suspended, but because they are sustained by the blowing of the Winds, or because they make with the subtile Matter small volumes as light as the Air ; or else, because all together they compose one entire Volume, which has some excess of surface in proportion to its mass. Therefore they may be rarefied in the Inflammation, as M. *Homborg* has observed^c ; and may be in equilibrium with the fine Air which surrounds them. This being granted, why may they not be inflamed at several times ? After Inflammation, altho' they be more subtile, yet are they still in equilibrium with the Air in which they float. Consequently they may remain therein, and be re-united. The Spring of the Air being compressed in the Inflammation, and dilated again, draws them near one another again ; the Vapours. in which they are enclosed, ought to contribute to retain and re-unite them, and their agitation makes them encounter one another.

^c Hist. de l'Acad. 1708. p. 2.

Hence,

Hence, the same Exhalations make new Mixtures ; new Mixtures make new Inflammations, and new Inflammations make those repeated Lightnings, which we see issue out of the same Cloud.

Eudox. These repeated Lightnings are sometimes like so many broken fiery Darts.

Arist. When the Fire of the Thunder contracted in a Cloud, forcibly bends the Spring of the surrounding Air, this Air by that means becoming capable of resisting it, is dilated, and contracted at different times, throws it back rapidly for several times successively, and only lets us see broken Darts of Fire.

Eudox. These Flashes of Fire threaten us with a Clap of Thunder.

Arist. When the Exhalation is compressed in the Cloud, the Inflammation, which produces those brisk Flashes, violently dilates the Air contained in the Exhalation and Cloud. The dilated Air compresses the neighbouring Air ; the bended Air unbends it self, communicating its alternate motion to the Air diffused as far as us. Hence the trembling of the Air, which makes a dreadful noise, being prolonged and redoubled by the Echo's of the Valleys and Mountains, as it were with Emulation.

The Action of the Sulphur and Bitumen, wrapt up in Vapours dissolved by the Inflammation, ought to contribute to the Thunderings, like Iron plunged into Water. Some

Phænomena

Phænomena that are pretty singular seem to confirm my Opinion. At *Quesnoy* the fourth of *January* 1717, the Weather being very cloudy, they saw in the middle of the Place, in a Cloud which seemed to touch the Houses, a Globe of Fire, which broke itself against the Tower of the Church, with the Crack of the Shot of a Gun, and spread itself over the Town like a Shower of Fire^d. 2. The seventh of *January* 1700, the Inhabitants of *Hogue* in lower *Normandy* saw a Fire in the Air, which had the shape of a Tree, and seemed to fall and lose itself in the Sea with a noise, which made two large Villages situated upon the Sea-coast to tremble^e. 3. M. *Lemery* mixed 3 Ounces of the Spirit of Vitriol with 12 Ounces of Water; when the Mixture was warmed a little, he strewed into the Vessel, at several times, an Ounce and half of the Filings of Iron. Immediately some white Exhalations issued out of it, which were lighted with the Flame of a Wax-Candle; and they became a kind of Lightning and Thunder^f. Finally, the noise of the *Pulvis fulminans* heated, and which is only a Mixture of Sulphur, Salt-petre, and Salt of *Tartar*^g, imitates and makes the noise of the Thunder sufficiently understood.

^d Mem. de l'Acad. 1717. p. 8.

^e Hist. de l'Acad. 1700. p. 10.

^f Hist. de l'Acad. 1700. p. 575.

^g Conversat. I. Vol. II.

Eudox. Nevertheless, it sometimes thunders without Lightning.

Arist. 1. In Chymical Operations, which are performed still better in the Clouds than in our Laboratories, there may happen a sort of cold Fermentations, as in Mixtures of Vinegar and Coral; and this sort of Fermentation never fails to make a noise without any Inflammation. 2. A Cloud dissolved by the heat may, in falling upon another, and compressing the Air intercepted between the two, produce a noise like that of Thunder, without kindling the Exhalations. 3. May not the Basis of the Cloud be so thick, that it deadens the Effort of the Inflammation, and withholds it from the Eye?

Eudox. All Lightnings ought at least to be followed with a Clap of Thunder.

Arist. The Inflammation is sometimes too weak to agitate the Air sensibly, because the Sulphurs of the inflamed Mixture are deprived of Salts, which are the principal cause of the noise. Besides, as Gun-powder is kindled without noise in a free space, because in that case its forces do not act at the same time, nor are sufficiently united for making the effect considerable; after the same manner an Exhalation too free, or which is not sufficiently contracted, is kindled without Thundering. The Thunder is only a Species of Gun-powder inflamed.

Eudox.

Eudox. But when the Thunder-clap breaks out, why does it follow the Lightning, tho' the Clap and Lighthing proceed from the Cloud at the same time?

Arist. Because the ethereal Matter which bears the Light, conveys the Impression which it hath receiv'd more swiftly, than the Air which conveys the Sound; because the ethereal Matter is finer, and is not compress'd, whereas the Air is groffer, and is compress'd: Because the Motion of Light is direct, and that of Sound undulatory.

Eudox. The Clap, which follows the Lightning, is ordinarily followed with a Shower of Rain.

Arist. The Inflammation, which causes the Noise, ought naturally to shake and dissolve a part of the Cloud, and make it fall down in Rain.

Eudox. When the Rain abounds, it scarcely thunders any more.

Arist. Because the Water which falls upon the Exhalations, drowns it, if I may so say; or carries it off, at least in part.

Eudox. But just now, *Aristus*, the Question is about darting out the Thunderbolt, or seeing it issue out of the Cloud. Ought it not always to ascend, receiving some excess of Levity in the Inflammation?

Arist. The Weight of the condens'd Exhalation, which is only inflam'd and consum'd successively, the excess of Resistance which it meets with in the upper part of the Cloud, deeper and colder, a Vortex of dissolved Va-

pours which surrounds it, being formed by the Inflammation; all this gives the Exhalation a Direction toward the Earth, and precipitates it like a Species of Rocket turned topsy-turvy,

Eudox. Should you see it issue out of the Cloud, you would believe you saw divers Fires shoot out at the same time.

Arist. Because the Exhalation issues out in several parts, or the Resistance of the Air separates it.

Eudox. What long Tracts of Fire! Do they touch both the Earth and Cloud at the same time?

Arist. The strong Impression which a Vortex of Fire makes upon the Eye, when it is darted out of the Cloud, subsists still, even when it is removed to a distance from it, and makes it to appear where it is not, as the Impression of a burning Torch, rapidly agitated, makes it to be seen where it is not, presenting to the deceived Eyes a long Train of Fire.

Eudox. The Fire of the Thunder turns round in its Fall, and describes a broken Line.

Arist. Because the Center of Gravity is not in the Center of Figure, and the different Parts of the inflamed Exhalation do not strike the Air with equal Forces. This is what makes it to go winding about in some sort, like small Squibs which they throw in the Air.

Eudox. Do you believe that the Exhalation always reaches the Earth?

Arist. When it is too light, so that it has not Matter enough to furnish Nourishment to the Flame,

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Flame, or is not sufficiently compress'd, it ought to be dissipated in the Atmosphere. Besides, the Air, nearest to the Earth, being more gross, has the more force to resist, and consequently it may often happen, that the Exhalation being repell'd, ascends and is dissipated without reaching us.

Eudox. But how can that, which comes to its swifter than the Wind, obey the Wind?

Arist. A Body impell'd by different Impressions, but such as are not diametrically opposite, complies with each in proportion to its Force. Wherefore, when I observe that the Wind can give the Thunderbolt a Direction toward my Closet, I shut it exactly; my Philosophical Constancy is the less mov'd on that account; and I philosophize a little more calmly upon the Nature and Effects of Thunder.

Eudox. The Thunderbolt very rarely happens to strike Men. It seems to avoid them designedly, and to attach it self to greater Objects; to Trees, great Towers, and the top of Mountains.

*Ferunt summos Fulmina Montes *.*

Arist. The Thunderbolt only follows the Laws of Physicks in this. For, 1. Bodies, which are more elevated, may cleave the Base of the Cloud, or force the Wind to carry off the Base of the Cloud by straitning its Passage, and by that means facilitate the Fall of the Exhalation upon them. 2. The Exhalation en-

* Horat. Od. Lib. 2. Od. 10. V. 11.

counters them sooner in its fall. 3. Such an Exhalation may reach them, as would be dissipated for want of Fuel, before it reach us. 4. Could the Exhalation reach us ; sometimes a reflected Wind, which makes it fly over our Heads, carries it upon the Top of a Tree, Tower, or Mountain.

Eudox. But, *Aristus*, are Trees cleft or rooted up, Bellfries uncovered, and Edifices thrown down, the Effects of an Exhalation ?

Arist. The Cold cleaves Trees ; may not an inflamed Exhalation dilate them so as to cleave them, especially when it is carried in a Whirlwind, which alone cleaves Trees, breaks, or roots them up sometimes, acting against the Branches as against so many opposite Leavers, twisting about, and making the Trunk of the Tree turn round ? An impetuous Wind uncovers Bellfries ; therefore an Exhalation, gross and more rapid than the Wind, may likewise do so. In short, an Exhalation, which with an almost infinite Velocity happens obliquely or horizontally to strike against a Wall, which it calcines, insinuating itself into the Interstices of the unhewed Stones, where it acts as Powder in a Mine, may detach the Stones so much the more easily, because in that case it has not their Gravity to overcome. The efficacy of a Body in Motion answers to the Velocity ; and some Stones below being carried off, the Wall falls down, and the Edifice is overturned. If the Exhalation be shut up, with its Vortex of Water

Water or Vapours, between two Walls of an Edifice, much after the same manner as Gun-powder kindled in a Mortar-piece, or in a Mine, the Walls being violently push'd on one side by the Effort of the Exhalation, without being equally sustain'd on the other, follow the Impression of the greater Force, burst, fall down, and are dissipated, as happens in a Mine.

M. *Deslandes*, an ingenious Philosopher,* whom Curiosity carried into a Village, whose Church had been entirely burnt down by Thunder, says, that in this Village situated near *Brest*, they had seen three Globes of Fire of three foot and a half in Diameter each, and that they were united together; that this large Vortex of Flame had come rapidly, and pierced thro' the Church two foot above its level with the Ground; that it had instantly killed two of the four Persons who were Ringing, and made the Walls and Roof of the Church to spring as a Mine would have done: so that the Stones, were confusedly scattered round about, some of them being carried twenty-six Fathoms, and others sunk more than two Foot into the Earth*.

Eudox. I am no longer surprized that the Thunder, when it falls in a close place, as a Room or Church, melts Metals, breaks Steel, and produces at once a number of different Effects.

* Hist. de l'Acad. 1719. p. 22.

Arist. The Flame of an Enameller's Lamp being driven, like a small Dart, by the Blast of a Bellows, very quickly melts Glass and Metals. Is it surprizing that the Fire of Thunder, much more rapid, melts Metals in the twinkling of an Eye? The Flame of Sulphur penetrates them at first; a piece of Sulphur being applied to some Steel red-hot in the Fire, reduces it to Powder. The variety of Effects produced at the same time, proceeds probably from this, that the Exhalation, which is not of a very strong Consistence, is divided into many inflamed parts by its encountering with a hard Body. Thus sometimes there have been seen three or four small separated Flames flutter about in a Room*.

Eudox. I should be more astonish'd if the Thunder should dissipate your Silver in your Purse, and your Sword in the Scabbard, without hurting either Scabbard or Purse, and that you should get rid of it for some Pistoles, and some Fright; or if it should drink up the Wine in the Cask, without piercing or hurting it.

Arist. Such like Facts are the Sport of the Thunder, or rather of the Imagination. Nevertheless, perhaps, they are not so impossible as they may appear to be. We see Salts spare the most tender Bodies, while they dissolve the hardest. Spirit of Nitre neither dissolves Wood nor Wax, and yet it changes Iron

* Mariotte, de la percussion des corps, p. 224.

into

into a Species of Liquor. From a mixture of Lime, Vinegar, common Salt, Nitre, and Sulphur, they extract a Salt which penetrates Iron, without causing in it any sensible Alteration^a.

From bituminous Matter they extract a Salt, which imperceptibly passes thro' the Pores of a Plate of Silverⁱ. The *Menstruum*, which finds a free Passage thro' a Body, makes no change in it. Can it pass thro' without some difficulty? It penetrates forcibly, agitates, shakes and dissipates the Particles which oppose themselves to its Passage. Cannot a light and subtile Exhalation act after the same manner in the Purse and Silver, the Sword and Scabbard? May it not penetrate the Cask without hurting it, as bituminous Liquor penetrates Silver? May not the Wine being heated exhale imperceptibly like new Wine?

Eudox. Probably you will believe me, *Aristus*, if I tell you that the Thunder one day passed between the Shirt and Skin of a young Man of my acquaintance, and that it did nothing to him except making a Trace on his back without hurting him.

Arist. Since the Flame of Spirit of Wine runs upon Linnen and the Hand, without burning either Hand or Linnen, why may not an inflamed Exhalation, almost spent, be so weak that it pass between the Shirt and Skin without burning them?

^a Mem. de l'Acad. 1713. p. 308.

ⁱ Ibid. p. 310.

Eudox. You will not surely, *Aristus*, allow the Thunderbolt to be a Stone.

Arist. A Stone does not kill without Contusion, as the Thunderbolt does, whose Sulphur sometimes stops the Passages of Respiration, and suffocates without any perceptible mark of a Wound.

Eudox. Although the Thunder be only an Exhalation, it is always terrible. What Means can be used to turn it aside? I discern a gloomy Cloud; and I hear a true Thunder roar.

Arist. The ringing of Bells, and the noise of a Cannon agitating the Air, repels or turns aside the Cloud which is advancing, and turning aside the Cloud, it disperses the Thunder which the Cloud bears along with it.

Eudox. Nevertheless the Noise seems sometimes to attract the Thunderbolt. For in *Lower-Bretany*, on the Night of the 14th or 15th of *April* 1718, in that part of the Coast which extends from *Landerneau* to *St. Paul of Leon*, the Thunderbolt fell upon twenty four Churches in which they were ringing. The neighbouring Churches, in which there was no ringing, were spared*.

Arist. The Noise seems to attract the Thunderbolt: but that is when it happens under the Cloud, because then the Air being strongly agitated, divides, agitates and weakens the Base of the Cloud, and by that means facilitates the Inflammation and Eruption of

* Hist. de l'Acad. 1719. p. 21.

the Thunder, which being darted out through the weakest part, falls vertically, or almost vertically upon the place from which the Noise proceeds. Thus slow and imprudent Ringers are often struck with Thunder. A Misfortune which they might prevent, if they were as good Philosophers, as they are zealous for the publick Good.

Eudox. Consequently it is of importance to know, at least nearly, at what distance the Thunderbolt is; but by what means may it be easily known?

Arist. By observing how often the Pulse beats between the Lightning and the Noise. If it beat six times, the Thunderbolt is about 6000 Paces distant. Five times? 5000. Four times? 4000. Threetimes? 3000, &c. For the Sound which comes successively, and from that part where the Thunder is, comes off at the same time with the Lightning; and according to the Experiments of the Royal Academy of Sciences, it advances about a thousand Paces during the beating of the Pulse, or in one Second. Wherefore, should the Noise immediately follow the Lightning, the Thunder is near; a Philosopher himself fears, if he is susceptible of fear. The Danger is pressing, or rather it is past; for the fall of the Thunderbolt is as quick as the Lightning. He who fears Thunder, says *Seneca*, has nothing to fear*:

* Quæst. Natural. l. 2. c. 59.

Nemo unquam fulmen timuit, nisi qui effugit.

Eudox. This heartens me, *Aristus*. And to prevent the Thunder, which we have just now heard from intimidating Philosophers; you should have explained to me your Sentiment upon the other Fires, which have been observed in the Atmosphere. But let us go and sup together; we shall talk of the News of the times; and then go and take the Air and divert our selves in a philosophical manner, by discoursing of the fallen Stars, *Ignes fatui*, Columns of Fire, and that *Aurora Borealis*, which has appeared so often of late Years, and ordinarily five or six hours at least before the Sun.





CONVERSATION IX.

*Upon fallen Stars, Ignes fatui, and
the Aurora Borealis.*

End. **A**T last, there is no more Thunder nor Cloud, what Pleasure! Acknowledge, *Aristus*, that there is no Spectacle more affecting to a Philosopher, than the Heaven all sparkling with Stars. Does it not grieve you to see one of them fall just now, leaving behind it a long train of Fire? Here is exactly what *Virgil* foretold us *:

*Sæpe etiam stellas, Cælo impendente, videbis
Præcipites Cælo labi, noctisque per umbram
Flammæ longos a tergo albescere tractus.*

Arist. The Heaven will not shine the less for that. This Species of Star is only a light Exhalation, almost wholly sulphurous, which is inflamed in the free Air, much after the same manner as Thunder in a Cloud, by the blowing of the Winds, or by the action of

* *Georg.* l. 1. v. 365,

the subtile Matter, and an Acid in the Sulphur. The superior part of the Exhalation kindles first, because it is lighter; since it is more elevated, it is also more inflammable. The Inflammation is communicated to the inferior part of the Exhalation, as in a train of Powder. Hence, this sort of Star seems to fall. And because the Communication happens so rapidly, that the Inflammation is in the Base of the Exhalation, when the Impression, which it makes upon the Eyes, yet subsists, we fancy we see a long train of Fire, which is properly no where else but in our Mind.

Eudox. Those Fires which repose themselves, or flow gently upon the Hair of Children, and of which *Virgil* also speaks*:

*Ecce levis summo de Vertice visus Iuli
Fundere lumen apex, tactuque innoxia molli
Lambere flamma comas, & circum tempora
pasci.*

The *Ignes fatui*, which sport upon the surface of the Earth, and which seem to fly from those who do not fear them, and to pursue those who do; the Fire *St. Elme*, which fastens to Masts and Sail-yards of Vessels after some Tempests; those Fires more elevated in the Atmosphere, and which they call Columns, Pyramids, horizontal Light, or else the Northern Aurora, &c. These are so many

* Virg. *Æneid.* l. 2. v. 682.

Conv.IX. *Of Ignis Fatui.* 141

Exhalations kindled almost after the same manner, as that Star which just now fell.

Arist. We are, I think, equally persuaded of it.

M. *Bernier* says ^a, that one Night, in a stifling Heat, among the Islands of the *Ganges*, he saw in the Thickets all shining with Glow-worms, some Fires which ascended every moment, sometimes on one side, and sometimes on another ; that two of them appeared extraordinary, of which the one was as it were a large Globe of Fire, and the second like a Tree in flames. What were those Fires, if not Exhalations?

A light Exhalation, coming out of the substance of a Man, may rest upon his Head, and shine without burning, almost like a Glow-worm. The *Ignis fatui* are Exhalations which proceed from Church-yards, and other sulphurous places, where there happens a Fermentation. In short, nothing is more common than these Fires in the Torrid-Zone. You would say that they sport, when they flutter about at the pleasure of the agitated Air. If they fly from you, when you advance, that is because you push the Air forward which bears them. If they seem to pursue you, when you run away from them, the reason is because the Air which bears them, takes possession of the place which you quit every moment. The Fire *St. Elme* is

^a T. 5. p. 155.

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only a viscous Exhalation, kindled upon the Sea by the Shock and Agitation of the Salts. Is an Exhalation, more extended, elevated, and lighted in the Atmosphere, but in a free Air, is it, I say, cylindrical? It is a *Column*. Is it terminated in an angular Point, having a large Base, in form of a Pyramid? It is a *Pyramid*. A Collection of inflamed Columns and Pyramids in a luminous and transparent Cloud, which is often observed toward the North, is what they now call an *Horizontal Light*, but formerly *Aurora Borealis*, because of its resemblance with the Morning-Star in brightness. Was not the name of *Aurora* fine enough? But what think you, *Eudoxus*, of the Northern Light?

Eudox. You may see, *Aristus*, in a Letter which I wrote, and of which I keep a Copy. It is somewhat long.

Arist. I shall find it too short.

*A Letter upon the Phænomenon of the
19th of October, 1726.*

S I R,

ON occasion of the Phænomenon, at which all *Paris*, except the Philosophers, were astonished, the nineteenth of this Month, and which the *French Gazette* justly calls a Northern Light: you demand my
Senti-

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Sentiment concerning what they call this Northern Light.

It is a Species of thin, transparent and luminous Cloud, which appears from time to time, upon the Horizon, in the night towards the North. Formerly they called it *Aurora Borealis*, because of its resemblance to the Morning in clearness.

At present it is sometimes an Horizontal Light, sometimes a Northern one. It has lost the specious Name of *Aurora*, probably because it generally precedes the Morning it self five or six hours at least. However that be, they have observed this Light in several Ages; but especially in our days. They observed it in 992^b, 993, 1621, 1707. And this Meteor has appear'd frequently all the following Years; from 1716 to 1726^c. They saw the same Species of Meteor, but with some difference in the Apparitions. In 992, on *Christmas* Night, you would have taken the Night itself for Day. In 993, on *St. Stephen's* Night, there was a kind of Morning-break. In 1621, on the twenty first of *September*, M. *Gassendi*, being near to *Aix* in *Provence*, saw on the North side a luminous Cloud, which possess'd 60 Degrees of the Horizon, between East and West^d. It was elevated in

^b Calvisius. Recueil d'Observations, par M. de l'Acad. des Sciences.

^c Hist. de l'Acad. 1716. p. 6. 1717. p. 3. 1718. p. 1. 1719. p. 1. 1720. p. 4. 1722. Mem. p. 1. 1726. p. 3.

^d Abrege de Gassendi, tom. 5. p. 245.

form

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form of a Bow, more than 40 degrees high, and darted out white and red Pyramids and Columns. In 1707, the sixth of *March*, there were Species of Rain-bows, out of which issued some luminous Rays, directed toward the *Zenith*; Phænomena usual in *Greenland*, *Norway* and *Iseland*, and almost continually in Countries near the Pole*. In 1716, the fifteenth of *March*, they perceived a Light toward the North-east, whose Base was embattel'd, and the upper part terminated in the form of a Spear, of the colour of Fire, and distinguished by sundry white Channellings, thro' its whole length. The seventeenth of the same Month, at *London*, they saw northward a kind of Gulf of reddish Light, which darted out its Rays from time to time, like lighted Rockets. These Rockets spread themselves, and formed Waves in the Air of a clear Smoak, but so transparent, that they saw the Stars thro' them, and so bright, that they discerned the Houses. M. *Maraldi*, who has exactly observed those Phænomena since 1716, has sundry times seen a great horizontal Light, whitish, like a transparent Twilight, and which permitted him to see the Stars. But in the Month of *April* 1716, the Columns ascended, says he, like Rockets, and one would have thought that they were so many Spouts of Light. The thirtieth of *March* 1719, they

* Gassendi, tom. 2. p. 100. Recueil d'Observations, par M. de l'Acad. des Sciences.

saw

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saw a Column of Fire elevated 20 degrees above the Horizon, between the North-nor-West and West, parallel to the Horizon, and extended 25 or 30 degrees. It obscured the Light of the Moon, altho' the Moon was in the eighth day, and very clear. People were affected with this Phenomenon, and a cry of Admiration was raised throughout all *Paris*. The eleventh of *February* 1720, M. *Maraldi* saw more Columns of Light, which had something in them still more affecting.

After all, Sir, I doubt whether before the Phenomenon of the nineteenth of this Month, any thing had been observed more marvellous toward the North, than what I saw at *Fleche* in *Anjou* the first of *March* 1721. Three quarters of an hour after seven a-clock in the Evening, I perceived on the North-side a transparent Cloud, which was extended almost from the North-east to the North-west; and seemed elevated from the North Horizon almost to the Pole. It was like an *Ellipsis*, whose small Diameter almost answered to the Meridian of *Fleche*. The Cloud appeared extraordinary to me. Near eight a-clock, I saw five luminous Columns arise suddenly on the part of the East. Three of them were dissipated quickly, and the two other, which were very long and perpendicular to the Horizon, past toward the West, sometimes stopping, sometimes recoiling; then again continuing toward the West, flowing always upon the

meridional Arch of the Cloud. Such kind of Columns were formed from time to time in divers parts. The Heaven was very serene. Half an hour after eight a-clock, a part of the luminous Cloud divided it self into different small Clouds, carried toward the South. But a little before nine they were united again to the great Cloud, and in this re-union I saw a great number of very bright Columns. At nine the Cloud was inflamed from the Eastern border to the West part; so that I saw a prodigious number of Rays, Cones, Pyramids, and Columns of Fire, which darted out on all sides. Many of those Columns seemed to bound over my Head. Their Flame was very gentle, white, and mixt with blue. In proportion as those Fires issued out of the bosom of the Cloud, especially on the South part, there were hollow slopes made in it; so that in a very little time, the South part seem'd gnawed to the Center. The inflammable Matter which came from the East part, filled up this Vacuity; and the same sport begun again toward ten. We saw the Matter of the Phænomenon arise incessantly above the Horizon toward the North-east, always from the same place. It seem'd sometimes to spread itself by Undulations; and now and then seeming Waves, flowing into certain obscure parts of the Cloud, were quickly inflamed. A quarter of an hour after ten, the Center of the Cloud

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Cloud seemed dissipated by the Inflammation, almost as far as the North Horizon. After this, I saw nothing more remarkable. This Phænomenon attracted the Attention of the whole Country.

The Phænomenon, which appear'd lately, has something in it still more astonishing, at least as to its Extent. About a quarter of an hour after seven in the Evening, they saw on the North side of *Paris* two Species of luminous Arcs, the one above the other, which extended from the West even beyond the North-east, or from the West toward the Summer Sun-rising. The greatest of those Arcs was elevated above the Horizon, almost 25 degrees, and sent off now and then some small Columns of a very white light. But toward eight a clock, such a prodigious quantity of Beams, Columns and Globes of Fire issued out of the two luminous Arcs all at once, that the Heaven was almost wholly covered with them, excepting about the height of 30 degrees toward the South. The Light formed a kind of Crown and Dome toward the *Zenith*. On the West part they saw a Cloud of a very bright red. They saw one much like it toward the East, but not so red. The Heaven successively assumed different Colours, which spread themselves over the Clouds. The Phænomenon lasted 'till ten a clock in its Splendor, with some changes however, sometimes more feeble, sometimes more

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luminous. After that, it recovered its vigour again from time to time; and they affirm*, that the *Aurora Borealis* appeared still toward the North, when the true *Aurora* shewed it self in the East.

This Phænomenon † spread terrour abroad. As for you, Sir, I don't believe that you are disposed to take those celestial Fires for Battles pitched in the Air, or Prognostications of some fatal Event. The new Philosophy has annihilated the greatest part of those Battels and Prognostics. The Fires, which the cold Climates of the North send us from time to time, are only Exhalations inflamed above the ordinary Clouds, but however within the Atmosphere. These Fires, I say, are elevated above the ordinary Clouds, since sometimes those Clouds happen to withhold them from our Eyes. Nevertheless they are in the Atmosphere. In short, they do not participate of the regular Motion of the Stars from the East toward the West, as M. *Maraldi* has observed. They are not inflamed Exhalations; for one sees them ascend above the Horizon, and to be inflamed in proportion as they ascend, when the Sun and Moon are for a long time below the Horizon. But why does the luminous Cloud appear sloped or dented, in proportion as the Rays, Pyramids, Columns, or Globes of Fire are darted out of its Bosom?

* Mem. de l'Acad. 1729. p. 207.

† Observé en divers endroits; à l'Obs. par M. Godin.

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Doubtless because the Exhalation being attenuated and dissipated by the Rarefaction, which happens in the Inflammation, becomes imperceptible.

Exhalations of this kind are probably sulphurous, bituminous, and nitrous Exhalations. We are no longer allowed to doubt, whether such Exhalations can take fire as of themselves, without the Aid of foreign Fire. There is nothing that kindles more easily than Sulphur and Bitumen. These oily Matters have a thousand small Cells full of Air, whose Spring is always bent, and of a subtile Matter, always rapidly agitated. Some farther degrees of Agitation; and the Particles of the small Cells being broken, will have this quick and universal Motion, which makes the Flame to sparkle in our Eyes. The blast of the Winds, or the rencounter and shock of Clouds, may add those degrees of Agitation, and cause the Inflammation. I have often seen, in the Northern Light, small Clouds inflamed by encountering one another. Neither is there any thing more required, to produce those sudden Inflammations, than an Acid in some sulphurous Matter. Mix a little Gun-powder with Oil of Cloves, pour upon this Mixture some citrine Aqua-fortis; you see at once a Flame of Cones and Globes of Fire issue out of the Mixture of two cold Liquors, and Gun-powder kindle, when one only pours Aqua-fortis upon it.

In proportion as the Exhalations are thus inflamed in the Air, according to the different Figures, different Consistence of the inflammable Matter, and the divers Reflections or Refractions of Light, one sees Rays, Cones, Globes, Pyramids or Columns of Fire issue out, under different Colours, from the luminous Cloud. If the Light is white, the reason is because the Exhalation contains no Vapours. The Vapours afford a red colour to the Light. That of the Sun is commonly considerably white, when he is much elevated; and red, when he is in the Horizon; because when he is in the Horizon, his Rays pass through more Vapours. Vapours afford very free Passages to a great quantity of Rays, but many Rays are stopt by the solid parts of Vapours. Free and lively Rays, but interrupted or mixt with Shade, diffuse a red colour over Objects*. Probably the two Clouds of a bright red, which they observed in the late Phenomenon in the middle of a white Light, contained plenty of Vapours.

But the Spouts of Light, sometimes white, sometimes red, or blue, which shoot out like Lightnings from the bosom of the Cloud, ought they not to be followed with so many Thunder-claps? Lightnings, which foretell Thunder-claps, are caused by the Inflammation of an Exhalation compressed in a thick Cloud. Wherefore, the forces of the inflamed Ex-

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halation being re-united by the resistance of the Cloud, and acting almost all at once, like those of Powder kindled in the Mouth of a Gun, strongly bend the Spring of the Air, and produce in the Air this alternate Motion, this impetuous Tremulation, which makes the noise, which the Echo's of Mountains and Rocks redouble and prolong. But the Inflammation of a rare, light, and free Exhalation ought not to cause this crack, because its forces are successively dissipated, and are not sufficiently united. By the same Principle, Gun-powder is also inflamed quietly and without noise, in a free space. Now, the Exhalation of a luminous Cloud is a rare, light, and free Exhalation, since it is transparent and elevated above the ordinary Clouds. Therefore these Fires ought not ordinarily to be accompanied with noise, as Lightnings are.

But finally, why are these Fires so frequent toward the Pole, and commonly proceed from Northern Countries? In the matter of Physics, it is allowed to venture upon some Conjectures, especially when one only offers them as Conjectures. Sometimes the least probable happen to be true, as the most probable are found to be false. The Vortex of magnetic and fine matter, which they make to circulate from one Pole of the Earth to the other, after M. *Descartes*, in order to direct the Poles of the magnetic Needle toward the Poles

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of the Earth, is still at least probable. What is it, pray, which gives the Needle this Direction, if not an insensible Matter, which has the same Direction? The Needle has it not of it self. It is only a small portion of Matter without Efficacy. Now this Vortex issuing out from the Pole, and those adjacent Countries, abundantly and impetuously, should it not carry off with it an extraordinary quantity of sulphurous and bituminous Exhalations, filled with this fine Matter, which might render them lighter and more inflammable? Proceeding from Northern Climates, they should render the Phænomena almost continual there, as they are. Being light, they should be elevated, as they are, above ordinary Clouds; and a blast of Wind should carry them; as one sees them carried, sometimes Southward, sometimes Eastward, and sometimes Westward. Being abundant, they might cover, as they did lately, a great part of the Heaven, and from time to time present to our eyes Spectacles, which spread terror amongst the Populace, the moment that they divert Philosophers, the undisturbed Spectators of a Heaven all on fire.

Nevertheless, a fact more certain, than my Conjecture, is that I have the honour of being, with profound respect,

Sir,

Your most humble, &c.

*From Paris, 28
Octob. 1726.*

This

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This, I think, is the *Aurora Borealis* set in its full light.

Eudox. The Rain-bow, tho' it often presents itself to our Senses, will perhaps have in it something still more entertaining and curious. You have already sufficiently made known to me your Sentiment upon this head *. I will now tell you mine,

* *Conversat. XXII. Vol. II.*



Con-



CONVERSATION X.

*Upon the Rain-bow.**Arist.*

Always find new pleasure in considering the Rain-bow, its Figure, and the Arrangement and Variety of its Colours. But this pleasure is not equal to that, which you give me in discovering the secret causes of it, according to your Principles.

Eudox. In order to explain my self upon this Phenomenon, I begin with some Observations.

1. They call the Iris or Rain-bow, those different Colours, disposed in form of a Bow, much like those of a Prism, and perceptibly spread over some Cloud opposite to the Sun.

2. When we have our Backs turned toward the Sun, and squirt out Water with the Mouth, or look upon the scattering of the Drops of a Water-spout, we observe the Rain-bow pretty well imitated upon the dispersed Drops. Wherefore, I distinguish two Rain-bows, the one

one artificial, the other natural. Art contributes to form the first; Nature alone forms the second. Such is the Bow described on a Cloud opposite to the Sun, and with which only our business is here.

3. Sometimes only one Rain-bow appears; sometimes one sees two at the same time, one internal, and the other external. Each of these Bows has three principal Colours; Red, Yellow, and Blue, which give rise to the other Colours.

4. In the internal Arc, the Blue is below, the Red above, and the Yellow in the middle. On the contrary, the external Arc has the Red inwardly, and the Blue outwardly.

5. I give to the visual Rays the name of the Colours, where they terminate. Hence, I call them red, yellow, or blue Rays.

6. The Line drawn from the Center of the Sun to the Center of the Iris, which passes thro' the Eye of the Spectator, I call the Axis of Vision, as they commonly do.

7. In the internal Arc, the visual Rays make with the Axis of Vision, Angles of about 41 degrees 14'; the yellow Rays, Angles of 41 degrees 30'; and the red Rays Angles of 41 degrees 46'. In the external Arc, the red Rays make Angles of about 51 degrees 46'; the yellow Rays, Angles of 52 degrees; and the blue Rays, Angles of 52 degrees 16'*. Let us first consider only the internal Arc.

* According to the Calculation of M. Rohault. 3 part. chap. 17.
This

This being granted, what makes the Rain-bow? The Rays of the Sun more or less broken in the Drops of Rain, and reflected to our Eyes with Vibrations more or less strong, and with more or less shadow. 1. The Rays of the Sun; for Colours are only Light modified, and the Iris does not appear but when the Sun enlightens the Horizon. 2. These Rays are broken, since almost all of them fall obliquely upon the spherical surface of the Drops, and the Rays, which are only reflected, do not give different Colours to Water. 3. They are, I say, Rays broken in Drops of Rain: One sees no Rain-bow but only in rainy Weather. 4. These Rays are reflected to our Eyes, since they convey to them, from the part of the Air opposite to the Sun, the impressions of different Colours. And this is done with Vibrations more or less strong, and with more or less shadow; for the Rays, which come from the superior part of the Arc, being less broken, since they make a larger Angle with the Axis of Vision, and the Angle which they make with the direct Rays answers to this Angle, have lost less of their force: Consequently, they strike our Eyes with stronger Vibrations. But as they are in the Convexity of the Arc, they are so much the more mixt with shadow, because they are nearer the ineffectual Rays. The Rays that come from the middle of the Arc being a little more broken, but between
the

the red and the blue, which sustain them, are a little feebler, but less interrupted, and less mingled with ineffectual Rays. Hence, the Yellow, which consists in Vibrations of Rays a little weakened, but without mixture of Shade, or little mixed with ineffectual Rays. The Rays reflected by the inferior part of the Arc, being more broken, since they make a smaller Angle, are weaker. By the same principle, they are more mixt with ineffectual Rays, and so much the more mixt with Shade, because they are found in the extremity of effectual Rays. Hence, the Blue, which consists in very weak Vibrations of Rays strongly mixt with Shade *.

Wherefore, as we have already said, when our Backs are turned toward the Sun, we see a kind of Rain-bow upon drops of Water, which the Mouth or Water-spouts squirt out; and if you place three small Balls of Glass full of Water, so that one be in the middle, the other below, and the third above, making with the Axis of Vision Angles of 41 degrees 14', 41 degrees 30', and 41 degrees 46'; or if you place the Eye successively below the same Ball, so that the visual Rays make those different Angles, you see the Colours of the Iris in their usual situation.

Arist. But the question is, *Eudoxus*, to discover the secret paths of the effectual Rays in the drops of Water.

* For the true Cause of the Colours in the Rain-bow, see *Conversat. XXII. Vol. II.*

Eudox. 1. The Rays of the Sun enter into the drops of Rain by the upper part. For if one cover the upper part of the small glass Balls full of Water, which represent the colours of the Iris, those Balls lose their Colours. 2. The Rays, the moment they enter the Drops, are broken more or less in proportion to the inclination with which they fall upon the Drops, and approaching the perpendicular, (*a*) Fig. 4. because they pass from a more difficult Medium into an easier one; namely, from Air into Water. 3. After they have entered, they proceed toward the opposite part, following the direction which they received in refraction. Many of them finding there a free passage in the Pores of the surface, go off, and are ineffectual. Many of them, which encounter solid Particles (*bcd*), are reflected downward, making an Angle of Reflection equal to the Angle of Incidence. 4. Those Rays being reflected, at least many of them, come forth by the inferior part (*efg*) removing from the Perpendicular (*i*), because they pass from an easier Medium into a more difficult one; namely, from Water into Air. 5. This diverging greater or less brings to us the effectual Rays, once reflected, and twice broken; and the difference of their Vibrations, more or less accompanied with Shadow, forms the different Colours of the Rain-bow.

Arist. But why are the Rays ineffectual, which do not make with the Axis of Vision such Angles as we have spoken of?

Eudox.

fig. 4.

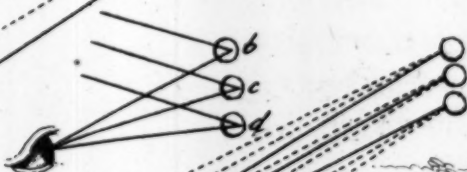
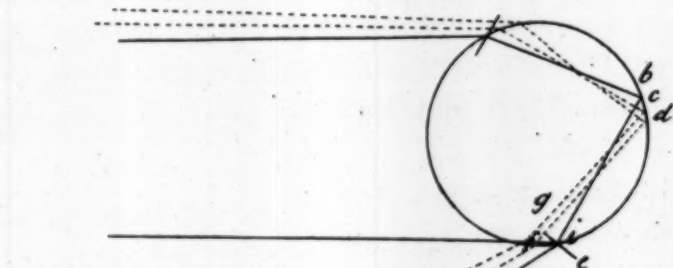


fig. 6.



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Eudox. Because their direction carries them above or else below the Eye; as one may see in Fig. 6. (*abcd*) where the Rays (*ad*, *bd*, *cd*) alone are effectual, because the other Rays do not terminate in (*d*), where the Eye is placed.

Arist. Hence, one immediately comprehends why the Iris has the figure of an Arc of different Colours. As all Rays of the same colour are almost equally distant from the Axis of Vision, they ought to be disposed in form of an Arc round about it; the red, yellow, and blue Rays make together a sort of Cone composed of several Surfaces diversely coloured. The superior Surface is red, the inferior blue, and that of the middle yellow. The Basis of the Cone is in the Cloud, which falls down into rain, and the point of it is in the Eye of the Spectator.

Eudox. Thus, two Men do not properly see the same Rain-bow; because they cannot have their Eyes at the same time at the point of the same Cone. The Cone differently coloured appears curtail'd. One does not see the Circle intire upon the Clouds.

Arist. One cannot see the Circle intire, unless some of the visual Rays come below the Axis of Vision, which make with the Axis Angles of about 41 degrees. Now none of them come. In order to that, it would be necessary, that the extremity of the Axis, which is in the center of the Arc, were elevated

vated about 41 degrees above the Horizon, and consequently that the other extremity, which is in the Center of the Sun, were as much below the Horizon. But if the Sun is below the Horizon, how can the Axis pass, as it ought, thro' the Eye of the Spectator?

If the Spectator were plac'd in a part elevated after such a manner, that he saw in the Center of the Sun the extremity of the Axis, which is in it, and the other extremity elevated 41 degrees above the Horizon, he would see the whole Circle.

Eudox. When the Arc is Westward, it diminishes continually; but when it is Eastward, it increases continually.

Arist. When the Arc is Westward, the Sun is elevated above the Horizon toward the East; the Extremity of the Axis, which is in the center of the Sun, ascends at the same time, and the other extremity descends; and consequently the Arc diminishes proportionally. By a contrary reason, when the Arc is Westward, it increases continually.

Eudox. By the same principle, the Northern Rain-bow appears sometimes in Winter, when the Sun is in the Meridian, but never in Summer. Because in Winter the Sun not being always at the height of 42 degrees in the Meridian, the other extremity of the Axis is not so far sunk below the Horizon, but that one can see some Segments of the Arc. But in Summer the Sun being elevated more than

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42, 50, and sometimes 60 degrees, the other extremity of the Axis ought to be more than 42, 50, or 60 degrees below the Horizon; and consequently there are no effectual visual Rays to make Angles of 41 degrees with the Axis of Vision.

Arist. When the Rain-bow appears, in vain do you attempt to come up to it, it seems always to fly before you. Do you fly from it? You would say that it affected to follow your Steps. One never finds one's self in a Rainbow, which one sees.

Eudox. Because it is always changing; when one goes forward or backward, new Rays that come from different Drops of Water strike the Eyes under the same Angles, and the Arc only appears at the Extremity of the visual Rays, which, with the Axis, make Angles of about 41 Degrees. If we were in the middle of the Arc, and saw it at the same time, we should see it when the visual Rays made, with the Axis of Vision, Angles of 90 Degrees.

Arist. Sometimes the Arc appears interrupted.

Eudox. Because the Cloud it self is interrupted, and there are some places which do not remit the Rays to our Eyes, or because the Interposition of some Cloud hinders the direct Rays from being broken and reflected in the Cloud opposite to the Sun.

Arist. The Business is now, *Eudoxus*, to explain what there is that is singular in the external Rain-bow.

Eudox. 1. In order to form this Arc, the Rays enter by the inferiour part of the Drops; for in Glass-balls full of Water, situated after such a manner as to represent the Colours of this Arc, and their arrangement, if one hinder the Rays from entering thro' the inferior part, the Balls are not coloured.

2. The Order of the Colours appears turned topsy-turvy in this Arc; because the Rays (*abc*), which the Drops receive, are received into it, and come out of it by a contrary order, Fig. 5.

3. Why are the Colours of it weaker? Because the Rays admitted below are weakened, not only three times as in the internal Arc, but four times, since they are reflected twice in every Drop, and twice broken.

4. The external Rain-bow appears farther distant, because it is weaker.

Finally, Sometimes we see two Rain-bows, at others only one appears. We see two, when at the same time drops of Rain fall both from the superiour and inferiour part of the Cloud; so that the visual Rays, which terminate in those Drops, make Angles of 41 Degrees, and Angles of 52 Degrees, or thereabouts. And but one appears, when the Drops only fall from the inferiour part of the Cloud, or when the Rays of the external Arc are too feeble.

Arist.

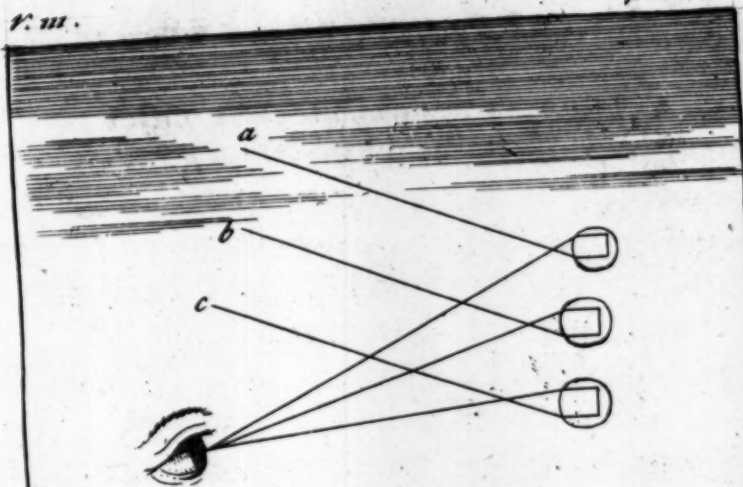
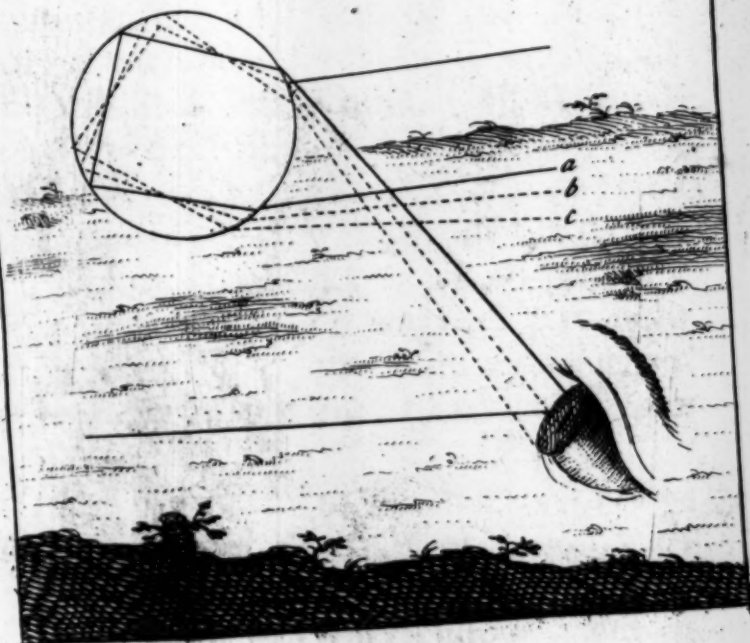


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Arist. After all, *Eudoxus*, a certain Person related to me a very rare Phænomenon, which at first appears somewhat difficult to be reconciled with your Sentiment. One day, when the Sun was elevated about 15 Degrees Eastward, and the Weather was the most serene that could be, so that the least Cloud did not appear; Father *Pardis*, who travelled on horseback, and passed over a stony Causey, considerably high, with astonishment perceived a Rain-bow turned topsy-turvy upon the Grass of the Meadow. The Colours of it were the brightest that can be seen. Here is at once a Rainbow turned upside-down, without Cloud or Rain*.

Eudox. Yow know the Fact; know you its Circumstances? The Grass of the Meadow was charged with small Drops of Water, which a thick Mist had left behind. These small drops of Dew remitting the broken Rays, like drops of Rain, made the same Colours appear; and as it was only the lowest part of the Conic Surface of the coloured Rays, which encountered the drops of Dew, it was that part only which represented in the Rain-bow turned topsy-turvy one of the finest Phænomena that ever was seen.

As for the large Crowns which appear sometimes round about the Sun or Moon, with some of the Colours of the *Iris*; they are probably Rays broken in a frozen Cloud; and of

* Journ. des Sçav. 7 Fev. 1667. p. 45.

a lenticular figure. In short, the Rays which penetrate Glasses made in form of a Lens, pass thro' and paint beyond those Glasses a Crown with different Colours, pretty like those of the Rain-bow.

Arist. But what do you think of the Parhelia?

Eudox. These are Images of the Sun, which appear sometimes near the Sun, environed with Colours much like those of the Rainbow. These false Suns are caused by the Reflexion and Refraction of Rays. Do the Rays fall in a Cloud upon a Plane formed of small pieces of Ice, and equally inclined toward the Sun, and toward our Eyes? They are reflected to us with an Angle of Reflection equal to the Angle of Incidence, and make us see the Image of the Sun upon the Cloud, much after the same manner as they often represent it upon a Plane of Glass, or upon the Surface of Water. A great number of Rays broken in small pieces of Ice, having the figure of triangular Prisms, may produce the Colours wherewith the Parhelia are accompanied. And now, *Aristus*, when you desire it, we will carry our Views above the Clouds, and attempt to discover what passes in the Heavens and Luminaries themselves.



CONVERSATION XI.

*Upon the PLANETS in general, and
the MOON in particular.*

Eud.  **W**HAT a pleasure there is in taking the Air with a Friend in such fair Weather? Is not a Night like this worth the finest Day to a Philosopher? Let us elevate our Views, *Aristus*. Is there any Spectacle so magnificent? I think I see traces of the Wisdom and Power of the Creator shine on all sides in this vast Liquid, in this bluish and immense Space. Those Luminaries, that Crescent, those Planets, those Stars, those regular and constant Motions; all these afford Admiration to any one who knows how to reflect upon what affects the Senses.

Arist. Are you well persuaded, *Eudoxus*, that those immense Spaces, in which the Luminaries roll over our heads, are a real Liquid? I have seen learned Persons, who seemed to doubt it.

Eudox. How should the Luminaries make the Light glance in our Eyes, with conveying

or reflecting luminous Rays from all parts ? But the Sun, Stars, and Planets, cannot convey or reflect luminous Rays from all parts, unless the immense Spaces, which enclose them, be a real Fluid ; the Rays of Light are a liquid and real Matter, as we have observed in speaking of Light * : therefore those Spaces are a real Fluid †.

In short, if the Planets, which we see turn round about the Earth, are not carried in a Liquid, which retains them in its bosom, why do they not incessantly remove farther off ? Bodies moved round incessantly make an effort, in order to remove from the Center of their Motion.

Arist. But, *Eudoxus*, among so many shining Luminaries, how do you distinguish the Stars from the Planets ?

Eudox. In a serene Season, the Stars commonly sparkle, and the Planets do not, or but rarely. Moreover, Stars always appear in the same situation with respect to one another ; and for this reason they are said to be fix'd. On the contrary, Planets are sometimes nearer, sometimes farther distant from one another. You would say they wander'd in the Zodiack, and for this reason we have given them the name of Planets. By these marks it is easy to discern them, when one has observed them for some time.

* Vol. II. Convers. 16.

† See Notes Conversat. 5. Vol. I.

Arist. If I was an *Icarus* or a *Phaëton*, my curiosity would quickly carry me into those Planets, that I might take a nearer view of what passes in them.

Eudox. You may know it without running so many hazards. The Aid of Telescopes alone discovers that to modern Astronomers, and makes the farthest distant Objects, as it were, present to us. Oftentimes also are they informed of Changes that happen twenty or thirty millions of Leagues distant from hence, while they are ignorant of what passes at *Paris*.

Arist. Well, *Eudoxus*, be pleas'd to impart to me what you have remarked in your Observations as most certain, most intelligible, and most curious concerning the Planets, as well in general as in particular, as if I had never studied any thing relating to them.

Eudox. They call the Heaven that liquid, immense, and blue Expansion, bespangled with a prodigious number of Bodies, which we see shine in it. These shining Bodies are the Luminaries. The Planets are so many Luminaries. They reckon 16 Planets, seven great ones, and nine small, which they call Satellites. The first are the *Moon*, the *Sun* in the ordinary System of the World^f, or the *Earth* in the System of *Copernicus*^g, of which we shall speak hereafter; *Mercury*, *Venus*, *Mars*,

^f Vol. I. Conversation 13. Fig. 15.

^g Ibid. Fig. 16.

Jupiter, and *Saturn*. The other are Species of little Moons, four of which incessantly move about *Jupiter*, and five round *Saturn*.

The Planets (I don't speak here of the Sun) are opaque and solid Bodies. For their interposition with-holds from us the Light of the superior Luminaries, and only reflect a borrowed Light; since they have their different Phases, that is, divers parts enlightened, or without light, in proportion as they change situation with regard to the Sun and Earth.

The simple Sight discovers in the Planets two Motions, one diurnal and common, from East to West, thro' Circles parallel to the Equator; and the other from West to East, but cutting the Equator, according to the Order of the Signs of the Zodiack.

The Planets have their Revolutions, or Returns to the Point whence they proceeded. They have their common and diurnal Revolutions, and their proper Revolutions. The first are made sensibly every day, from the East towards the West. The second are made from the West toward the East, in very unequal times. The Moon accomplishes her proper Revolution in twenty seven Days and eight Hours, or thereabouts; *Mercury* in three Months; *Venus* in seven and an half; the *Sun* in a Year; *Mars* in two; *Jupiter* in twelve; and *Saturn* in thirty.

While the Planets make their Revolutions, they are sometimes nearer, and sometimes farther

ther distant from the Earth. For they appear a shorter time,¹ and much larger in certain parts of their Circle, than in others; and the apparent bigness of Objects answers to their distance *. The Point where Planets are farthest distant from the Earth, is their *Apogee*. The Point where the Planets are least distant from the Earth, is their *Perigee*.

As Planets have their Apogea and Perigea, they have also their *Aphelia* and *Perihelia*. The Perihelia of Planets is their greatest proximity to the Sun, and their Aphelia is their greatest distance from it.

Whether the Planets be in their Perigee, Apogee, or middle Distance, they are nearer us than the Stars, since they withhold the Stars now and then from our sight.

Hence Planets have their Conjunctions, Oppositions, and Quadratures. They are in Conjunction, when they are under the same celestial Sign, and in a Line drawn from the Eye to that Sign. They are in Opposition when they are in Signs directly opposite, or 180 Degrees distant. They are in Quadratures, when their reciprocal distance is three Signs, or 90 Degrees.

This being granted; let us call to mind the appearances of every Planet in particular, and begin with the Moon: this is the Planet least distant from the Earth.

* 20 Convers. Vol. II.

Arist. By what mark do you know, *Eudoxus*, that the Moon is nearest us?

Eudox. Because she obscures the other Planets from our sight^h. They observed two Eclipses by the Moon in 1715, the one of *Venus*, and the other of *Jupiter*ⁱ: One of *Mars* in 1726^k, the 18th of *January*; and one of *Saturn* in 1482, the 12th of *January*^l.

Arist. Well, let us begin with the Moon, and in the first place give me a Description of her upon the Report of Telescopes, Astronomers, and your own Eyes.

Eudox. 1. One cannot doubt but that the Moon is an opaque and solid Body. For not only are the same parts of the Moon sometimes enlightened, and sometimes obscure; but when she happens to be directly between the Sun and our Eyes, she deprives us of the Light of the Sun, she loses her own, and is cover'd with darkness, when the Earth is between her and the Sun.

2. The Moon is a spherical Body. Being looked upon with or without Glasses, it presents us with a Figure sensibly round. And why do we see it in the form of a Crescent? Because the part illuminated, which strikes our Senses, is an Arc of a Circle. A Plane, which obliquely receives the Light, does not give it this Figure.

^h Kepler. Astron. Par. Optica, p. 306, 409.

ⁱ Hist. de l'Acad. 1715. p. 54.

^k Mem. de l'Acad. 1726. p. 260.

^l Kepler. Astron. Par. Optica, p. 306, 409.

3. In the obscure part of the Moon, they discover Species of luminous Points ^m. Are they not Heights, little Hills, Rocks, and Mountains? According to the Observations of *Kepler*, Father *Riccioli*, and Mr. *de la Hire* ⁿ, the Moon is a very rugged Country, covered with an infinity of Mountains higher than ours. And M. *Cassini* says, that he saw a Mountain in the Moon, whose height seemed to exceed three Leagues^o, tho' there are none known upon Earth, whose perpendicular height is one League. With Telescopes they discern the Shadow of those Lunar Mountains, and observe it to change according to the different Aspects of the Sun ^p. Between those Mountains are Cavities, Pits, or very deep Caverns, hollow in a thousand and a thousand places. The Light being reflected by the Sides of the Mountains, makes us discern them. On the contrary, the Cavities that absorb the Light which they receive, make in some measure those obscure Spots which we see upon the Globe of the Moon. I say in some measure; for there are places, which without being Cavities are obscure. They are probably large Countries, the Land of which is naturally blacker, or more proper

^m Taquet. l. 8. Astron. Tract. 3. n. 5.

ⁿ Kepler in *Diff. cum nuntio sidereo*. Riccioli [Alm. T. 1. l. 4. p. 208. Mem. de l'Acad. 1716. p. 110.

^o Mem. de l'Acad. 1724. p. 405. Hist. p. 88.

^p Taquet. l. 8. Astron. Tract. 3. N. 5.

for

for absorbing the luminous Rays in its Pores, much after the same manner as Coal.

Arist. Should not those obscure large Countries rather be Seas?

Eudox. In those Countries they observe Cavities; which is what does not agree to Liquids, as Seas. But would you believe it, *Aristus*? From the Quadratures or Quarters to the Opposition of the Moon with the Sun, a great number of Cavities and Mountains cease to be discern'd; and of obscure parts become luminous.

Arist. I see very probable Reasons for that. 1. Those Mountains being enlightened on the side in the Quadratures, their Eminencies become sufficiently perceptible to our Eyes, by reason of the multitude of reflected Rays: but in the Opposition, neither the Points nor Eminencies of those Mountains are sensible enough, because the Mountains being enlightened in the Front, do not direct Rays enough toward our Eyes. The jutting out of the Figures in Basso-Relievo, placed at a moderate distance, is more easily seen when the light shines on the side of it. 2. Many hollow places, which appear black in the Quadratures, only then receiving oblique Rays, may naturally become luminous and brilliant in the Opposition; because then being seen fully by the Sun, they are Species of large concave Mirrours, whose internal, solid and rugged Surface, remits the Rays of Light livelily and on all sides.

But

But if the Cavities of the Moon have their internal Surface, solid and without Water, the Moon ought then to have no Atmosphere.

Eudox. Accordingly she has none, at least sensible. If the Moon had a sensible Atmosphere, we should perceive some change in a fix'd Star, or Planet, that approach'd too near to the Discus of the Moon, and visibly touched it. The passage of the Rays thro' this Atmosphere, and their Refraction, would change the Situation, Splendour or Colour of the Stars. Now, the most attentive Observators of those kind of Changes have remarked none of them in this Case. The Moon eclipsed *Venus* the 28th of *June* 1725 *. Mess. de *Malezieu*, *Cassini*, and *Maraldi* observed, each with a different Glass, and very attentive to the Circumstance under Consideration; and, neither in the Immersion nor Emerfion, that is, when *Venus* was upon the Point of being concealed by the Moon; or when it began to appear again, did they see any change, either in its Motion or Figure, or Colour. They perceived nothing of it, no more than *M. de la Hire* did in the time of other Eclipses of the Planets by the Moon, whether by Day or Night.

It is true, that some skilful Observers † saw *Venus* in the same Eclipse suddenly change

* Mem. de l'Acad. 1715. p. 132.

† M. Le Chevalier de Louville, & M. de Lisle.

colour upon Immerſion and Emerſion ^e. But ought not this change to be referred to the Perspective Glaſſes. Thoſe Glaſſes ſometimes diſſuſe Colours over Objects, and the ſame Colours over divers Objects ^h. Eſpecially, when the hole of the Objective is large, they make the Colours appear toward the Edges of the Perspective, and not toward the Centre; the Edges of the Objective being as it were a Circular Priſm, which affords the ſame Colours as a Triangular one. In ſhort, make a fix'd Star enter into a Perspective: the brim of the Star which is toward the Axis of the Perspective, becomes red, and the other blue; but the red and blue are defaced when the Star is upon the Axis, or in the Center of the Telescope ⁱ. Thus, leſs than a Month after, the 25th of *July*, Meſſ. *de la Hire*, *Caffini*, *Maraldi*, *de Louville*, and *de Liſle*, obſerv'd an Eclipse of *Jupiter* and it's Satellites, by the Moon, without ſeeing in it any change, whether of Figure or Colour, when it was in the Center of the Telescope, and in a Situation where its Rays would have been naturally broken by the Atmosphere ^k. Finally, the 21ſt of *April* 1720, M. *Caffini* ſaw the Moon eclipse two fixed Stars, without changing them the leaſt in the world, either as to

^e M. de l'Acad. 1715. p. 135.

^h Le P. Dechales, T. 3. Afr. l. 3. p. 364. Prop. 2.

ⁱ Hiſt. de l'Acad. 1715. p. 56.

^k Mem. de l'Acad. 1715. p. 148, 151, 155, 159. Hiſt. p. 58.

Distance,

Distance, Figure, or Colour ¹. Therefore, the Moon has no Atmosphere, at least no sensible one.

Arist. But, when it is fair Weather, and the Moon is in her Decrease, or, in her Encrease, as at present, why do we still see this Luminary's Body, at least confusedly?

Eudox. Because the Rays of the Sun being reflected by the Earth toward the obscure part of the Moon, make it appear at least confusedly, as the Rays of the Sun, reflected by the Moon upon the Surface of the Earth, would make it seen by Eyes which looked upon it from the Moon. Accordingly this second Light of the Moon is much more lively, when the Moon is still near the Sun, than when she is in her Quarters^m; because, when she is near the Sun, the obscure Part receives the Light reflected by the whole Surface of the Earth, which is wholly opposite to her, and which is all enlightened with respect to her. But when the Moon is in her Quarters, where her Distance from the Sun is 90 Degrees, there is only the half of this Surface enlightened, which can diffuse its reflected Light upon the obscure Part of the Moon, and these Rays being more oblique, are reflected in smaller number to our Eyes. Hence, when the Moon is in her De-

¹ Mem. de l'Acad. 1720. p. 141.

^m Taquet. Astronom. l. 8. Tract. 3. n. 3, 4. Dechales, T. 3. p. 367.

crease ⁿ, and approaches to her Conjunction, this reflected Light is stronger, because it proceeds from Eastern Countries, where there are fewer Seas. In the first Phases after the new Moon this Light is weaker, because it proceeds from Western Countries, where there are more Seas. The Land remits more light than Water.

Arist. We may easily comprehend why the Moon is sometimes New, sometimes Full, in her Encrease, or in her Decrease, Fig. 7. The Moon (*a*) is new in her Conjunctions, or when she is between the Sun (*b*) and the Earth (*c*); because then the illuminated Hemisphere of the Moon faces the Sun in such a manner, that it is no wise turned towards us, or scarcely presents to our Senses a luminous Arc. The Moon (*d*) is full in her Oppositions, or when the Earth is between her and the Sun; because then the illuminated Hemisphere of the Moon faces us at the same time that it is turned towards the Sun. Lastly, in proportion as the Moon removes from, or approaches to the Sun; she is in her Encrease (*d*), in the Quadratures or Quarters (*e f*) and in her Decrease (*g*), because she offers to our Eyes more or less of her illuminated Hemisphere. But how many Motions do you distinguish in the Moon?

ⁿ Suchij è S. I. Optica Philosophia, p. 252. Taquet. l. 8. Tract. 3. n. 3. S. 4.

f. m.



fig. 7.

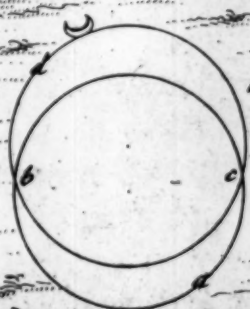
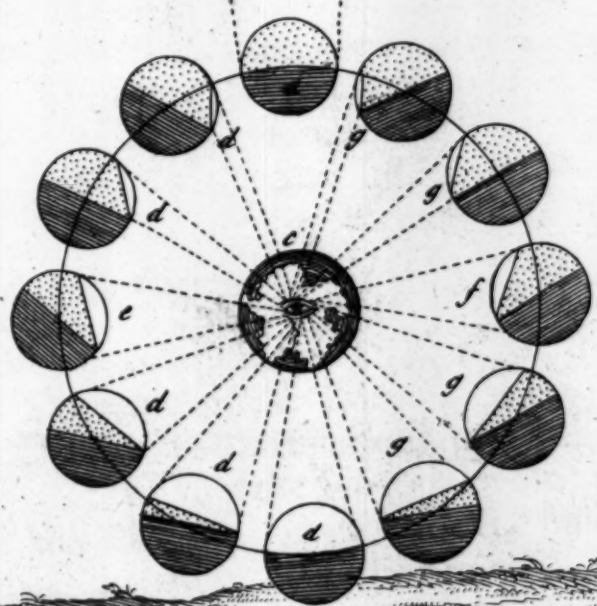


fig. 8.

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Eudox. Three, at least; two, whereof we have spoken already, namely one common and sensible from *East* to *West*, and the other proper from *West* to *East*; and a third, upon her Center. The Moon (*d*) accomplishes her Revolution from West to East in twenty seven Days and eight Hours, or thereabouts, making Angles of about five Degrees with the Ecliptick (*a*) Fig. 8. which it cuts in two Points (*b c*) *. But she is not found to be in conjunction with the Sun, till after twenty nine Days and an half, or thereabouts; for while it has made its periodical Revolution, or has return'd to the point of the Heavens from which it departed, the Sun has run thro' about 27 Degrees of the Zodiack, from West to East, since he makes almost one Degree every Day. And that the Moon may run over those 27 Degrees, be joined with the Sun, and be found in conjunction, more than two Days are required; for she only makes about 13 Degrees in a Day †.

Finally, As M. *Cassini* has observ'd, the Moon ought probably in every one of her Revolutions to make one Revolution upon her Center, since she always presents to us the same Spots, and consequently the same Hemisphere. Describe a Circle always facing the Center of the Circle, and you make an entire Revolution upon your self. This is, as if you made

* Riccioli Almag. nov. T. 1. l. 4. cap. 12. p. 218, 219.

† Riccioli Almag. l. 4. c. 18. p. 238. Hist. de l'Acad. 1723.

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one without coming out of the Center. In short, whether you run over a Circle always facing the Center, or you make an intire tour upon your self, still abiding in the Center; I, who am without the Circle not moving, see successively, your Face, one Side, your Back, the other Side, then your Face again.

However that be, the Moon has her Changes. They discovered in her at *Rome*, the 25th of *August* 1725, in the presence of the Cardinal *Polignac*, a new and very considerable Light in that part which they call *Plato*, (for in honour of the great Philosophers they thought fit to give their Names to divers Countries of the Moon.) They saw the same Light in this Planet the 22d of *September* 1727. It seem'd to possess the 32d Part of the Diameter of this Luminary *.

Arist. There is probably some separation of Mountains made therein; or some Country become more hard and solid, has begun to reflect the Rays with more force and vivacity.

Eudox. Are you willing, *Aristus*, that we pass from the Planet most accessible by the naked Eye, to that which is least so, even to the Telescope? It is *Mercury*.

Arist. To-morrow we will speak of *Mercury*, and other Planets. You have taught me News of a World very far distant from us: you will, perhaps, be well pleas'd to learn some of this here.

* Observations de la Planete de Venus, par M. Bianchini. Mem. de Trev. 1729. p. 1039, 1040. Juin.



CONVERSATION XII.

*Upon Mercury, Venus, Mars, Jupiter,
and Saturn *.*

Arist.  ELL, shall we see *Mercury* this Evening?

Eudox. You would say that he affects to conceal himself from the Eyes of the most attentive Astronomers, so rare a thing is it to perceive him.
He

* Besides the similitude that there is betwixt the Planets and our Earth with respect to the Bodies of them, and the Things contained in them; there is also another similitude between them with regard to external things, *viz.* The Phænomena of the celestial Motions, and the mutual Aspects of the Planets observed from thence. Which subject *Huygens in his Planetary Worlds, Book II.* having treated very pleasantly and very astronomically, we will here pick a few things out of him; and will suppose, that there are some rational Creatures in every one of the Planets, capable of observing the Motions and Phænomena of the Heavens from thence.

To begin then, says he, with the innermost and nearest the Sun; we know that *Mercury* is three times nearer that vast Body of Light than we are: whence it follows, that they see him three times bigger, and feel him nine times hotter than we do. Such a degree of Heat would be intolerable to us, and set on fire all our dried Herbs, our Hay and Straw that we use. And yet

180 *Of Mercury, Venus, Mars,*

He shines more than the other Planets, and appears less. Being always near the Sun, he hides himself in that very Light which environs him.

Arist.

yet there is no doubt, but that the Animals there, are made of such a Temper, as to be but moderately warm, and the Plants such as to be able to endure the Heat. The Inhabitants of *Mercury*, 'tis likely, have the same Opinion of us as we have of *Saturn*, that we must be intolerably cold, and have little or no Light, we are so far from the Sun.—The Astronomy of those that live in *Mercury*, and the appearance of the Planets to them, opposite at certain times to the Sun, may be easily conceived by the Scheme of the *Copernican* System. At the times of these Oppositions, *Venus* and the Earth must needs appear very bright and large to them. For if *Venus* shines so gloriously to us, when she is but like the Moon a little after it is new; she must necessarily in opposition to the Sun, when she is full, be at least six or seven times larger, and a great deal nearer to the Inhabitants of *Mercury*, and afford them Light so strong and bright, that they have no reason to complain of their want of a Moon. What the length of their Days are, or whether they have different Seasons in the Year, is not yet discovered,——but his Year is scarce the fourth part so long as ours.

The Inhabitants of *Venus* have much the same face of things as those in *Mercury*, only they never see him in opposition to the Sun; which is occasioned, by his never removing above thirty eight Degrees or thereabouts from it. The Sun appears to them larger by half in his Diameter, and about twice as big a Face, as to us, and by consequence affords them but twice as much Light and Heat, so that they are nearer our Temperature than *Mercury*. Their Year is completed in seven of our Months and a half. In the Night, our Earth, when it is on the other side of the Sun from *Venus*, must needs seem larger and brighter to *Venus* than she ever does to us.

But *Mars* has some parts of him darker than other some: by the constant returns of which, his Nights and Days have been found to be of about the same length with ours. But the Inhabitants have no perceivable difference between Summer and Winter, the Axis of that Planet having very little or no Inclination to his Orbit, as has been discovered by the Motion of his Spots. Our Earth must appear to them almost as *Venus* does to

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Arist. If we should not see him at present, I shall comfort my self, provided you describe him to me such as he appears, when the attention of Astronomers can surprize him.

Eudox.

us, and by the help of a Telescope, will be found to have its Wane, Increase and Full, like the Moon.——His Light and Heat is twice, and sometimes thrice less than ours, to which I suppose the Constitution of the Inhabitants is answerable.

In *Jupiter* the length of their Days are equal only to ten of our Hours; but their Years are equal to twelve of ours, and they enjoy a perpetual Equinox there. The Sun appears to them who are upon it five times less in Diameter than it does to us, and consequently they have but the twenty-fifth part of the Light and Heat that we receive from it. But that Light is not so weak, as we may imagine, as is plain by the brightness of that Planet in the Night; and also from hence, that when the Sun is so far eclipsed to us, as that only a twenty-fifth part of his Disk remains uncovered, he is not sensibly darkned. But if you have a mind exactly to know the quantity of Light that *Jupiter* enjoys, you may take a Tube of what length you please, let one End of it be closed with a Plate of Brass, or any such thing, in the middle of which there must be a Hole, whose breadth must have the same Proportion to the length of the Tube, as a Chord of six Minutes bears to the Radius; that is, about as one is to five hundred and seventy. Let the Tube be turned so to the Sun, that no Light may fall upon a white Paper placed at the End of it, but what comes thro' the little Hole at the other End of the Tube. The Rays that come thro' this will represent the Sun upon the Paper, of the same brightness that the Inhabitants of *Jupiter* see it in a clear Day. And if you remove the Paper, and put your Eye in the same place, you will see the Sun of the same magnitude and brightness as you would were you in *Jupiter*. If you make the Hole twice as little in Diameter, there will fall upon the Paper and upon the Eye, the same Light as the *Inhabitants of Saturn* have. And although this Light be but a hundredth part of ours, yet you see it makes *Saturn* shine tolerably bright in a dark Night. Further, they in *Saturn* can see but one of the other Planets, and that is *Jupiter*; so likewise they in *Jupiter* can see only *Saturn*, for the rest are too near the Sun to be seen. The fixed Stars, by reason of their immense distance, may be seen from *Saturn* and *Jupiter* in the

182 Of Mercury, Venus, Mars,

Eudox. 1. This Planet scarcely ever removes from the Sun; it is never distant above 28 Degrees ^a or thereabouts. 2. Hence, notwithstanding the use of Telescopes invented or improv'd about the beginning of the last Age, *Mercury* rarely appears, because he is almost always lost and swallowed up as it were in the Light of the Sun. 3. He passes before the Sun, and sometimes eclipses a very small part of it, invisible to the naked Eye. You only discern upon the Discus or Hemisphere of the Sun, a kind of an obscure Point: *Gassendi* saw it there in 1632. *Kepler* had foretold the event. Since this Observation, which

very same manner, and in the same figures, and distinguished with the same inequality of Light, as we see them. It is not to be doubted but that *Saturn* by his five Moons, and *Jupiter* by his four, have a great Advantage above us with our one Moon. But the most surprizing Phænomena, must necessarily be produced by that Ring, which we mentioned surrounding him. There is also a very great difference between Summer and Winter in *Saturn*, because of the great Inclination of his Axis to the place of his Orb, which is thirty one Degrees, whereas ours is but twenty three Degrees and an half. A Year in *Saturn* is equal to thirty of our Years; but what the length of one Day is, is not yet found out.

Lastly, The Moon is divided into two Hemispheres in such a manner, that they who inhabit one of them, have always a sight of our Earth, and they who inhabit the other never see it at all. They also see our Earth much larger than the Moon appears to us (and which is very wonderful) hanging always at the same height above the Horizon as if it never moved, and turning about its Axis in twenty four hours, and its light encreasing, full, and decreasing every Month. The Moon also receives from us fifteen times as much light as we from it: The Sun also rises and sets once in every Month of ours, which makes the Days and Nights very long.

^a Hist. de l'Acad. 1706. p. 106.

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passes for the first ^b, they have made five or six others of the same sort ^c. One such Observation alone is a Conquest, a Triumph for an Astronomer. 4. It evidently follows from this, that *Mercury* is an opaque Body, and shines only with a foreign Light. Accordingly he has his different Phases, Fig. 9. according as he is differently situated with respect to the Sun and Earth.

Sometimes he scarcely presents to our Eyes one small luminous trace (*a*), because being between the Sun (*b*) and the Earth (*c*), he only presents to us a very small part of his enlightened Hemisphere. Sometimes he is like a Species of little Moon in its Increase (*e*), in his Quarters (*f*), &c. because in a middle distance he turns toward us a greater part of his luminous Discus. Sometimes he is a sort of full Moon. His luminous Discus appears intire, or almost intire ^{*}; because being above or beyond the Sun, he presents to our eyes his whole Hemisphere, or almost his whole Hemisphere enlightened [†]. If the Hemisphere does not appear whole and intire, the Reason is probably, because there are some inequalities in the Planet, or some parts not so proper for reflecting Light. 5. If

^b They say however, that one was made in 807. Kepler. Astron. Par. Optica, p. 306.

^c Hist. de l'Acad. 1706. p. 104.

^{*} P. Scheinerus, S. 1. in Disquis. Mathem. N. 38.

[†] P. Riccioli Almag. Tom. 1. lib. 7. p. 484. Kepler. Epist. Astron. p. 762.

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Mercury were always between the Sun and the Earth, he would scarcely present to us one small part of his enlightened Hemisphere. If he were always at the same distance, on the right or left, he would never appear full. If he were always above the Sun, one should never see him in form of a Crescent. He would always appear round, or almost round. He must therefore move round about the Sun.

Mercury can't be sometimes on this side, sometimes above or beyond, and sometimes on the side of the Sun, without moving round about this Luminary. 6. The Circle which he describes about this Luminary, he accomplishes in about three Months *. 7. This Circle is excentrick. It is nearer the Sun in some of its Points, and farther off in others. Indeed *Mercury*, which runs thro' it, is sometimes nearer the Sun, and sometimes more remote. The difference of its greatest and least distance is about ten degrees †.

Mercury has his Perigeon and Apogeon ; since sometimes he is on this side, and sometimes beyond the Sun. And what will perhaps surprize you, in his Perigeon he appears less than in his Apogeon, altho' in his Perigeon he is nearer us.

Arist. I apprehend the Reason of it. Because in his Perigeon, as he is between the

* Découverte de la Lumière Céleste dans le Zodiaque, p. 26.
Receuil d'Observations, par Mess. de l'Acad.

† Kepler Epist. Astr. p. 763.

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Earth and the Sun, he scarcely presents to our Eyes any part of his enlightened Surface; and in his Apogee he shews us this Surface intire, or almost intire, being then above the Sun, which is between the Earth and him.

Eudox. Finally, *Mercury* has more brightness than *Venus* herself ^d, because he is nearer the *Sun*. Nevertheless the Appearances of *Venus*, of this shining Planet, which is going to descend below the Horizon, are more sensible. 1. *Venus* moves round the *Sun* as *Mercury*; for like *Mercury*, she is sometimes below, sometimes above, sometimes on the side of the *Sun*, and like *Mercury*, she has her different Phases ^e. 2. Her distance from the *Sun* is not always the same. Wherefore her Circle is excentrick ^f. 3. The Circle which she describes, is larger than that of *Mercury*. Accordingly, one sees her farther distant from the *Sun*. Notwithstanding she never removes farther than about 48 degrees ^{*}. 4. Her Circle cuts the Ecliptick, and makes with it an Angle of three degrees and an half. 5. There is no doubt but that *Venus* is an opaque and solid Body. For she has, much after the same manner as *Mercury* and the *Moon*, her different Phases ^g, according to her different Situa-

^d Galilée Dial. 3. de Mundi Syst. Riccioli Almagesti, T. 1. l. 7. p. 484.

^e Riccioli Almagesti, T. 1. l. 7. c. 4. p. 495.

^f Ibid. p. 485.

^{*} Kepl. Epist. Ast. p. 763.

^g Ric. Alm. T. 1. l. 7. p. 495.

tions,

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tions, with respect to the *Earth* and the *Sun*, which affords her light^h. 6. *Venus* is a very bright Planet by reason of her largeness, solidity, inequalities proper for reflecting Light on all sides, and nearness to the *Sun*. According to the Observations of M. *Cassini*, the Diameter of *Venus* is about 2822 common Leagues; and her Globe almost equal to that of the *Earth*. With a Glass of sixteen Foot, she appears three times bigger than the *Moon* does to the naked Eyeⁱ. Notwithstanding her brightness, she has her Spots^k, much after the same manner as the *Moon*. They have lately observed those Spots at *Rome* with a Glass of *Campani*, one hundred and fifty Palms long, and made by the Order, and at the Charges of Cardinal *Polignac*. M. *Bianchini* made Observations in 1724, 1726, 1727: He made them, I say, in 1726 with Cardinal *Polignac*, from the ninth of *February* to the tenth of *March*. And the Spots were discovered to their discerning Eyes, in as distinct a manner as one sees the Spots of the *Moon* without Glasses. There are seven principal Spots toward the Equator of the Globe of *Venus*, and two others toward the Poles. M. *Bianchini* concluded from the return of the Spots, that the Revolution of *Venus* upon

^h Ibid. p. 484. M. del'Ac. 1700. p. 290.

ⁱ Ibid.

^k Ric. Alm. T. 1. lib. 7. p. 485. M. de l'Acc. 1700. p. 290. Rec. d' Obs. du progrès des Astr. p. 37.

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her own Axis is accomplished, not in twenty three hours *, as had been conjectured, but in twenty four days and about eight hours †. M. *de la Hire* observed therein several times, inequalities more considerable than those of the *Moon*¹. This Disposition, almost frightful, may contribute to render the Planet so bright and comely at a distance. Nothing reflects Light more lively, at a great distance, than a number of Rocks very elevated and dry.

Mars has much less splendor than *Venus*; especially when he is not in his Perigeon. Do you see that Luminary whose Light is reddish, and which does not twinkle? It is *Mars*.

Arist. Well, what are the Appearances of *Mars*?

Eudox. 1. *Mars* accomplishes his Orbit in the Heaven in two years, or thereabouts; that is, in a Year and ten Months and a half, making with the Ecliptick an Angle of one Degree fifty Minutes. He contains within his Circle both the *Earth* and the *Sun*, since he does not pass between the *Sun* and the *Earth*. Thus, is he nearer the *Earth* in his Oppositions, and farther distant in Conjunctions; 2. He has different Phases, according to his

* Du progrès de l'Ast. p. 37.

† Observations de la Planete de Venus. Mem. de Trev. Juin. 1729. p. 1038, 1039, 1040, 1041.

¹ Mem. de l'Acad. 1700. p. 290.

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different situation with respect to the *Earth* and *Sun*^m. For he appears full in his Oppositions and Conjunctions; because then the whole Hemisphere presented to us is illuminated by the *Sun*. But in his Quadratures we only see one part of the Hemisphere that faces us, the other not being enlightened, because it is not turned toward the *Sun*.

3. When *Mars* is in opposition with the *Sun*, or when the *Earth* happens to be between the *Sun* and *Mars*, he is in his Perigeon, and when he is in his Perigeon, especially if he is in his Perihelion at the same time, he seems to be nearer the *Earth* than the *Sun* itselfⁿ, and so big and luminous, that one would take him for a new Planet^o. 4. When *Mars*, Fig. 10. is so near us, one sees in him, with Prospective Glasses, Lines or Spots^p, some clear, others obscure. The first are parts which remit the Light livelily; the others are places which reflect it but weakly. From the Revolution of those Spots they conclude, that the Planet makes a Révolution upon its Axis^q in twenty four Hours and forty Seconds^r. Large Spots are often seen to disappear in it after some Years, or some Months;

^m Riccioli Almagesti. T. 1. l. 7. p. 496.

ⁿ Elémens de l'Ast. p. 34. par. M. Cassini. Recueil d'Observ.

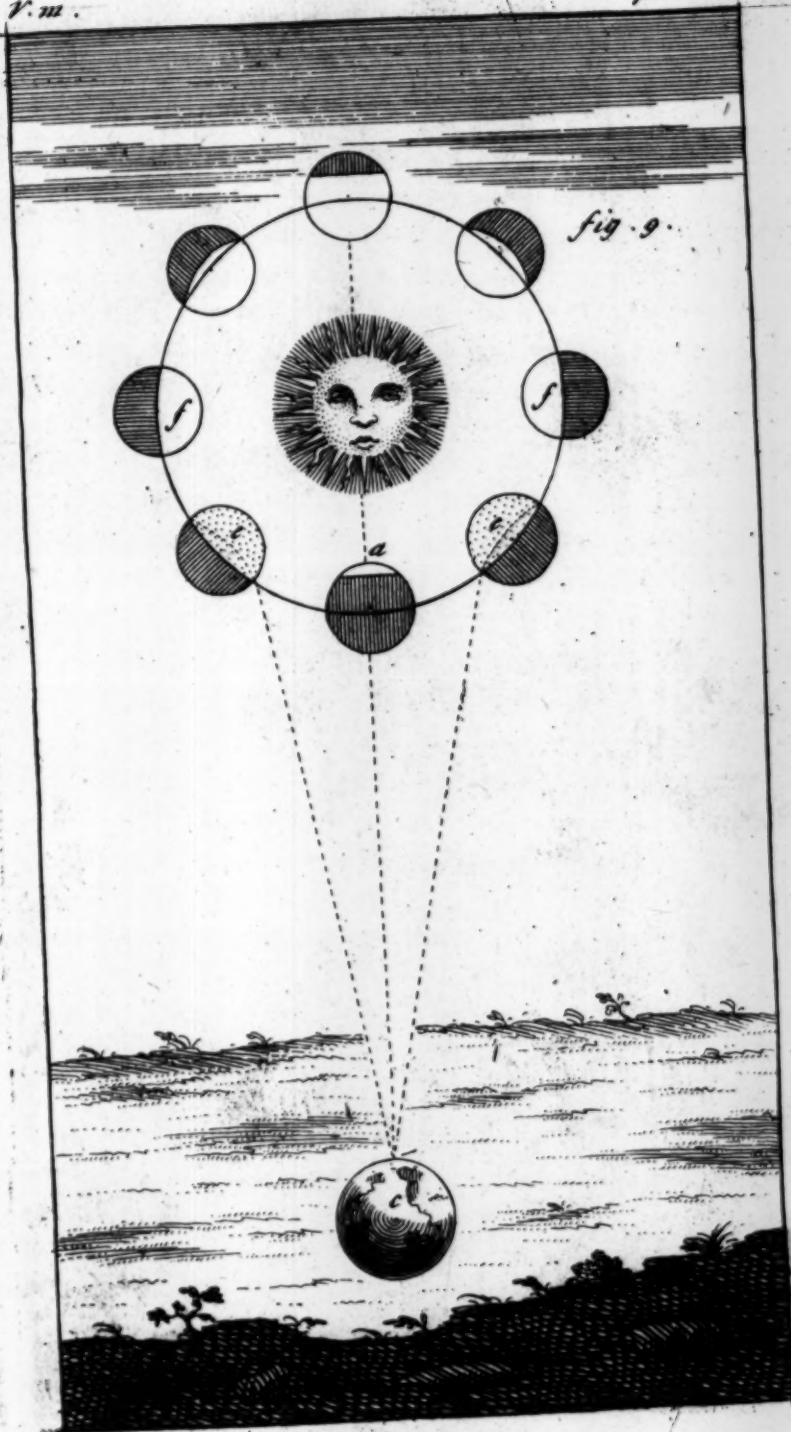
^o Kep. Astr. pars Opt. p. 333. Mem. de l'Acad. 1720. p. 145.

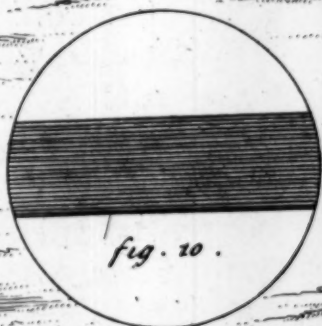
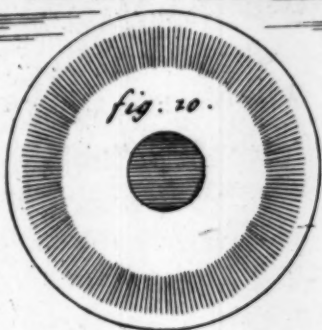
^p Ricci. Almag. T. 1. l. 7. c. 2. p. 486.

^q Ricci. Almag. T. 1. l. 7. c. 2. p. 486.

^r Mem. de l'Acad. 1720. p. 146. Du progrès de l'Astron. Recueil d'Observ. par Mess. de l'Acad. p. 37.

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while they see others formed and subsisting for several Months, and several Years ^f.

Arist. Therefore some strange Changes must happen in *Mars*, since they are perceptible at such a distance; and the Surface of the *Earth* must be very quiet in comparison of that of *Mars*. For scarcely has there happened, for the space of 4000 Years, any sensible change upon the Surface of our Globe.

Eudox. Our Lands, great Ridges of Mountains and Seas, only present us with changes, which would not be perceived from *Mars* with the best Glasses. Nevertheless the *Earth* must have had considerable Revolutions; for in a word, Trees sunk to very great depths, and Shells and Skeletons of Fishes buried in Lands and Mountains, are sufficient proofs of it.

Since the *Earth* and *Mars* have their Changes and Spots, it is natural that *Jupiter* has also his Spots and Changes. You may see, *Aristus*, this Luminary in the middle of the Heavens, whose Splendor is lively, without twinkling? This is *Jupiter*. Altho' he is larger than *Venus*, he is less bright.

Arist. The Reason of this, no doubt, is because being farther distant from the *Sun* and us, than *Venus*, he receives from the *Sun* a fainter Light, and the excess of Distance weakens it still more in the Reflection which is made of it to our Eyes.

^f Mem. de l'Acad. 1720. p. 151, 152, &c.

Eudox.

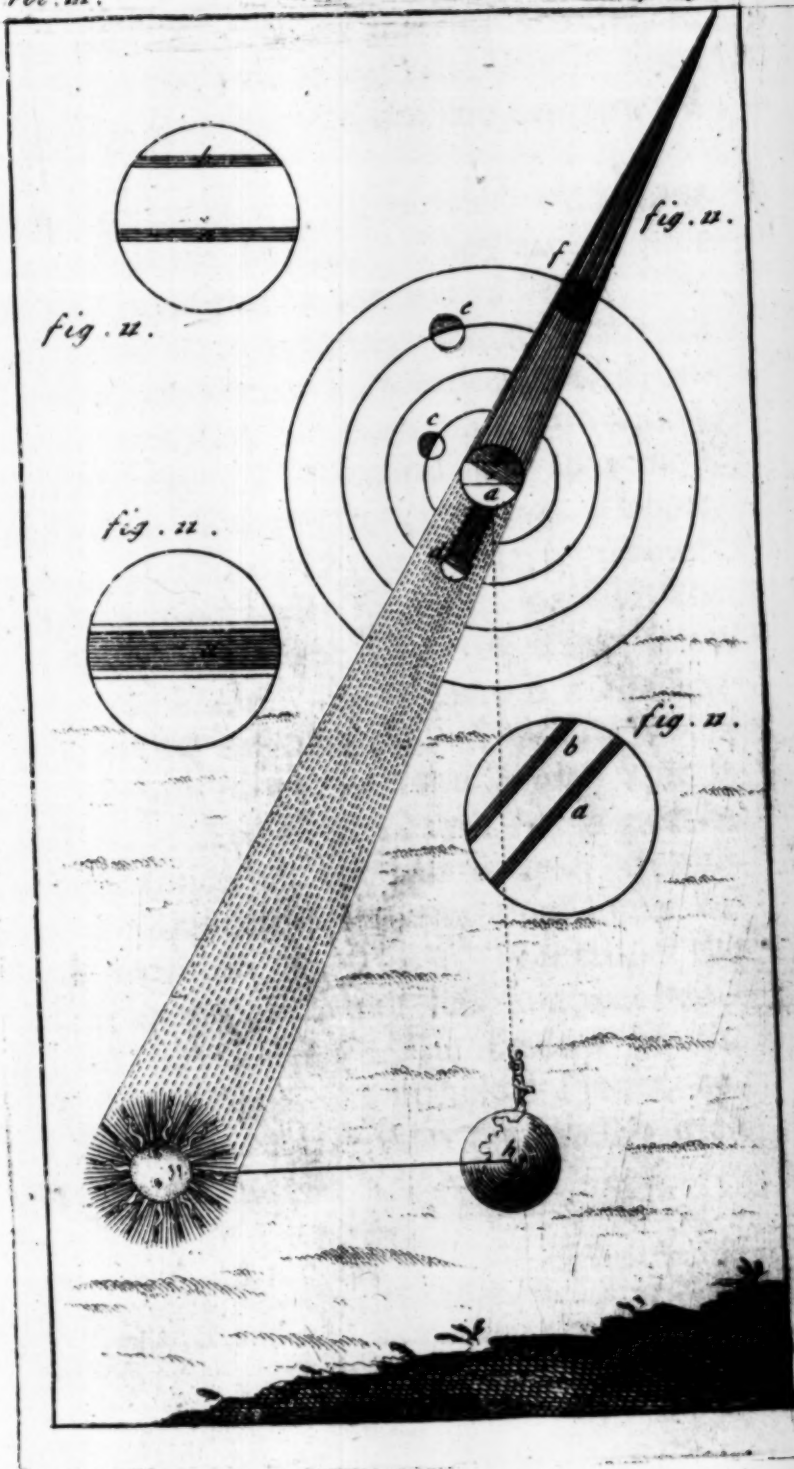
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Eudox. *Jupiter*, Fig. 11. has his different Phases, as the other Planets. He has his Spots (*ab*) in form of Belts sometimes more, sometimes less numerous; sometimes larger, sometimes smaller^t, by reason of the Inequalities of his Surface, parts less proper for remitting Light and Changes which happen therein, as in *Mars*, whether by the Action of the Rays of the *Sun*, or by that of the subtle Matter which penetrates the Planet. You see that those Belts shrink after many Years, or are enlarged, or interrupted, and after that united again. Some new ones are formed, and some are defaced. Changes more considerable, than if the Ocean should overflow the entire firm Land, and leave new Continents in its place. The Spots which are nearer the apparent Center of *Jupiter*, have a quicker Motion than the others, which have a larger Circle to run thro' in the same time. They see the same Spots move from East to West, disappear, and then appear again after nine Hours and fifty six Minutes^u. Whence they conclude that *Jupiter* turns round upon his own Axis, and makes a Revolution in ten Hours, some Minutes less. In this Revolution, the upper part of the Planet moves from the West

^t Riccioli Almag. l. 7. c. 2. p. 486.

^u De l'Origine & du Progrès de l'Astronomie Cassini. Recueil d'Observations, par M M. de l'Academie, p. 36. Découverte de la lumière céleste, &c. p. 24. Mem. de l'Acad. 1699. p. 104, 106. Hist. p. 78.

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towards the East, and the inferior Hemisphere moves from the East toward the West ^x, since one sees the Spots move from the East toward the West.

This Luminary is surrounded with four Species of little Moons. They are its four Satellites, invisible to the naked Eye. The first (*c*), that is to say, that which is nearest to *Jupiter*, makes its Revolution round this Planet in one day, 18 hours, and 22 minutes, or thereabouts. The second (*d*), in 3 days, 3 hours 14'. The third (*e*), in 7 days, 9 hours, 42'; and the fourth (*f*) in 16 days, 3 hours, 2'. When they are in Conjunction with the Sun, they hinder one Cone of Light from reaching the Planet. And there is a Shadow (*g*) which they cast upon it. This Shadow is a kind of Spot moveable upon *Jupiter*; it is an Eclipse. And if the Earth (*h*) is not in the same Line, we see this Eclipse, or this changing Obscurity run over the Discus of *Jupiter* from East to West ^y. Sometimes the Satellites appear greater or less, without being more or less distant. The shadow of the fourth spread upon the principal Planet, appears sometimes larger than the Satelles itself which is the Cause of it ^z.

^x Ric. Alm. T. 1. l. 7. p. 489.

^y Du progrès de l'Astron. par M. Cassini. Recueil d'Observ. par MM. de l'Acad. p. 38.

^z Mem. de l'Acad. 1707. p. 295.

Arist.

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Arist. Because probably they have their Spots, obscure parts and places more or less proper for reflecting Light. When they turn toward us their more solid parts, and more proper for remitting the Light, they appear bigger. The more luminous objects are, the more apparent bigness they have, because in that case the Impression is more extended upon the Retina^a. But if the Satellites present to us their Spots, or parts capable of absorbing the Light, they thereby appear the smaller, because the reflected Light paints a smaller Image upon the Organ of Sight.

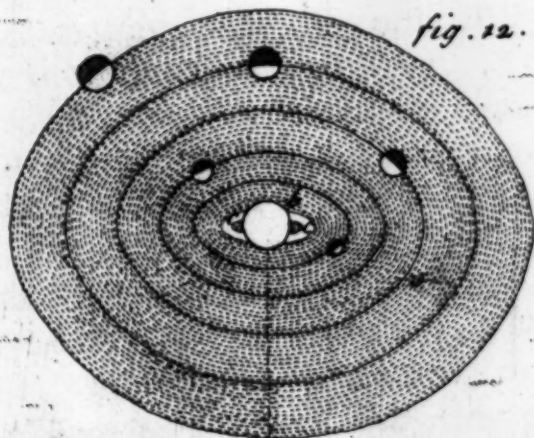
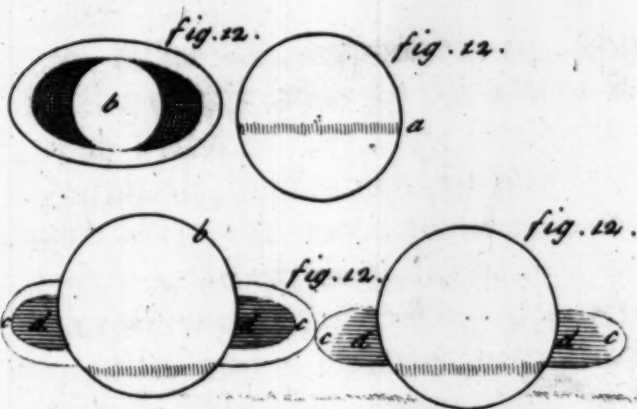
Eudox. In fine, *Galilæus*, who first discovered the Satellites of *Jupiter* with a Telescope, in the beginning of the last Age, gave them the specious Name of *Medicean Stars*^b.

As for *Saturn*, 1. He has his different Phases, as well as *Mars* and *Jupiter*, and changing Belts^c. 2. He appears sometimes round (*a*), Fig. 12. Sometimes elliptick (*b*). Sometimes they see in him two Species of Ears (*c, c*), which appear and disappear from time to time. Those Ears are like two luminous Arcs of a Circle, and directly opposite; which contain, each, an obscure Segment (*d, d*). These obscure Segments are con-

^a 20 Convers. T. II. p. 357.

^b Nuncii Syderei. p. 17, &c. Riccioli Almag. T. I. p. 488, 489.

^c Hist. de l'Acad. 1705. p. 44.



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tain'd between the Ears and the Globe of the Planet.

In order to explain these Appearances, M. *Huygens* ascribes to *Saturn*, a Ring (*cc*), whose Plane is very large, and the thickness very minute, and which surrounds the Planet, much after the same manner as the Horizon surrounds an artificial Globe. The external circumference of the Ring appears elevated more than 18000 Leagues above the Surface of *Saturn*^r. This Ring seems to be nothing else but a Mass and Train of Satellites so near one another, that they only make an appearance of a continued Ring. The Ring happening to be between the *Sun* and *Saturn*, projects a moveable Shadow over *Saturn*; and this is a Species of Belt.

The sight of the round Phasis, of the elliptick Phasis, or others, depends upon the position of the Ring, both with respect to the *Sun*, and with respect to our Eye.

Does the Plane of the Ring pass thro' our Eye? We do not see it; because the back or edge of the Ring is all that one can see of it; and it is too minute to be perceptible at so great a distance. Wherefore *Saturn*, whose Globe is spherical, appears alone in his round Phasis, which is what is observed from fifteen Years, to fifteen Years^r.

^r Hist. de l'Acad. 1715. p. 45. Mem. p. 46.

^t La Découverte de la Lumière Céleste qui paroît dans le Zodiaque, p. 25. Recueil d'Observ. par Mess. de l'Acad. des Sciences.

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But the Position of the Ring changes; the Plane of the Ring is inclined to the visual Ray, and faces us obliquely at the same time it receives the Rays of the *Sun*. One part of the circular Plane is hid behind the Globe, and another part is situated before the Globe, to which it appears applied without letting the intermediate Space be seen; and confounding its Light with that of the Globe of the Planet, it gives the apparent Discus the figure of an Ellipsis.

In short, among Circles of a Sphere seen at a certain distance, those, whose Plane passes through our Eye, are seen in a direct Line, and the others appear in form of Ellipses, more or less large, according as the visual Ray, which passes from our Eye to the Center of the Circles, is more or less elevated above their Plane.

While the inferiour part of the circular Plane of the Ring confounds its Light with that of *Saturn*, one discerns two opposite Portions of the Ring almost equal, which are at the two extremities of one of its Diameters prolonged, and contain two obscure Segments (*dd*). Those two opposite Arches are called the Ears or Handles of *Saturn*, by reason of their figure.

Arist. The obscure Segments contained between the Ears and the Globe of the Planet are probably two intervals of ethereal Matter, incapable of reflecting the Light, and intercepted

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cepted between two opposite extremities of the Globe of the Planet, and two opposite parts of the Ring.

Eudox. Lastly, if the Ring happen to be so plac'd, that its prolonged Plane pass thro' the center of the Sun, there is nothing but the back of the Lamina or of the Ring which receives the Rays of the Center ; and as this Lamina is minute, and its back narrow, it escapes our sight. At the same time each Surface of the Plane of the Ring receives Rays but from one half of the Sun, and very obliquely. Wherefore, the Surface, which may face us, remits to us too little Light ; and a Light too oblique and too faint to be perceived at such a distance. Hence the Ears disappear. The Light of *Saturn* is feebler than that of other Planets.

Arist. I am not surprized at that. This Planet is much farther distant from the very Source of Light.

Eudox. Notwithstanding his distance, we see that he hath five Satellites, by the help of Telescopes. M. *Huygens* discovered the fourth, counting by their distance from the principal Planet, and M. *Cassini* the other*. The first of the Satellites compleats its Revolution in about one Day and 21 Hours ; the second, in 2 Days and 17 Hours ; the third, in 7 Days

* Découverte de la Lumière céleste dans le Zodiaque. Recueil d'Observations, par Mess. de l'Acad. p. 21.

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and 13 Hours ; the fourth, in 15 Days and 22 Hours ; and the fifth, in 79 Days and 22 Hours ^u. The fourth was discovered in 1655. The fifth in 1671. The third in 1672. The first and second in 1684 ^x. The Satellites move in their Revolutions round about the principal Planet, and as the primary Planet, from the West toward the East, in the superior part of their Circle ; and in the inferior part, from East to West ^y. The fifth Satellite of *Saturn* augments and diminishes in bigness without any regard to its distance ; and in every Revolution it remains a long time hid toward its greatest digression Eastward ; altho' the other Satellites are never better seen than in their greatest Digressions.

Arist. Because probably the whole Surface of the fifth Satellite is not equally fit to reflect the Light, and turning upon its own Axis, it presents to the Earth its less luminous Hemisphere, when it is not visible ; and its most luminous Hemisphere, when it is clearly seen.

Eudox. Henceforth, *Aristus*, we may turn our Eyes toward the Source itself of the Light, and fix them without any danger upon the Sun itself.

^u Hist de l'Acad. 1705. p. 117.

^x Mem. de l'Acad. 1716. p. 205, 208, 210, 212, 215.

^y Hist. de l'Acad. 1716. p. 57.



CONVERSATION XIII.

Upon the SUN.

Arist.  T last, *Eudoxus*, what is the *Sun*, this so wonderful Luminary, whose Absence or Distance spreads a kind of Horreur over Nature, but whose Return animates it again, covering the Earth with Harvest, Flowers, and Fruits? He unveils to my Eyes whatever sensible Objects have in them most affecting; and yet, if I may so say, he remains in darkness with respect to my Mind.

Eudox. 1. The Sun is a Globe of Fire*, bigger than the Earth, and on all sides surrounded

* Since the subtle Matter and Vortices so often mentioned have been shewn to be entirely fictitious and contrary to the Phænomena of Nature; let us hear what the Illustrious Sir *Isaac Newton* says so incomparably well concerning the Nature of the Sun and Stars from other Principles. "Do not great Bodies, *says he*, conserve their Heat the longest, their Parts heating one another; and may not great dense and fixed Bodies, when heated beyond a certain Degree, emit Light so copiously, as by the Emission and Re-action of its Light, and the Reflections and Refractions of its Rays within its Pores, to grow still hotter, till it comes to a certain period of Heat, such as is that of the Sun? And are not the Sun and fixed Stars

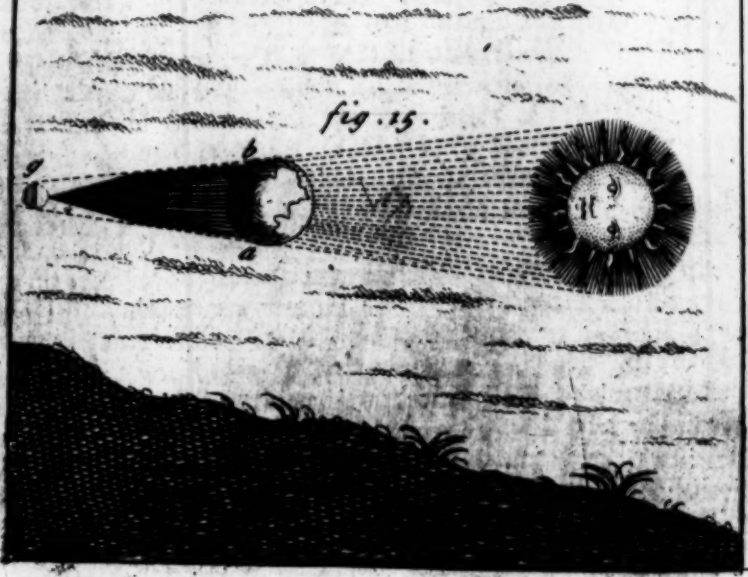
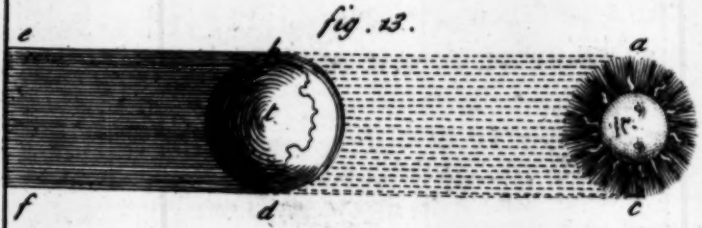
rounded with etherial Matter. It is a Globe, I say. It appears like a Discus to the naked Eye; but with Telescopes we see the Convexity of the Hemisphere which faces us. It

“ great Earths vehemently hot, whose Heat is conserved by the
 “ greatness of the Bodies, and the mutual Action and Re-action
 “ between them and the Light which they emit, and whose
 “ Parts are kept from fuming away, not only by their Fixity,
 “ but also by the Weight and Density of the Atmospheres incumbent upon them, and very strongly compressing them, and
 “ condensing the Vapours and Exhalations, which arise from
 “ them? For if Water be made lukewarm in any pellucid Vessel,
 “ and that Vessel be afterwards emptied of Air, that Water in
 “ the *Vacuum* will bubble and boil as vehemently as it would do
 “ if heated much hotter in a Vessel set on the Fire in the
 “ open Air. For the Weight of the incumbent Atmosphere
 “ keeps down the Vapours, and hinders the Water from boiling,
 “ until it grow much hotter than is requisite to make it boil in
 “ *vacuo*. Also a mixture of Tin and Lead being put upon a
 “ red-hot Iron in *vacuo*, emits a Fume and Flame; but the
 “ same mixture in the open Air, by reason of the incumbent
 “ Atmosphere, does not so much as emit any Fume, which
 “ can be perceived by sight. In like manner the great Weight
 “ of the Atmosphere, which lies upon the Globe of the Sun”
 (For the Weight of Bodies upon the Superficies of the Sun, is to the Weight of Bodies upon the Superficies of the Earth, as the magnitudes and density of the Sun is to the magnitude and density of the Earth) “ may hinder Bodies there from rising up
 “ and going away from the Sun in the form of Vapours and
 “ Fumes, unless by means of a far greater Heat than that
 “ which on the Surface of our Earth, would very easily turn
 “ them into Vapours and Fumes. And the same great Weight
 “ may condense those Vapours and Exhalations as soon as they
 “ shall at any time begin to ascend from the Sun, and make
 “ them presently fall back again into Him, and by that Action
 “ encrease his Heat; much after the manner, that on our
 “ Earth the Air encreases the Heat of a culinary Fire. And the
 “ same Weight may hinder the Globe of the Sun from being diminished, unless perhaps by the emission of Light, and a very
 “ small quantity of Vapours and Exhalations.” *Newt. Opticks.*
 p. 318.

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is a Globe of Fire; since it enlightens, warms, sparkles and shines like terrestrial Fire. Lastly, it is a Globe larger than the Earth, if the Shadow which the Earth projects when opposite to the Sun proceeds still diminishing its Diameter; for if the *Sun* (*s*) Fig. 13. was of the same Diameter with the Earth (*t*), the Rays (*ab*, *cd*) which would glance upon the Earth, would be parallel, and consequently the Shadow (*efbd*) contain'd between those Rays would never diminish. If it were less, the Rays (*ab*, *cd*) Fig. 14. which grazed upon the Earth would diverge, and the Shadow contained between them would augment in bigness. Now the Shadow of the Earth (*abc*) Fig. 15. still diminishes in Diameter; otherwise it would be diffused upon the superiour Planets (*g*). It would eclipse them; and it only eclipses the Moon (*b*). Therefore the *Sun* is a Globe of Fire, larger than the Earth. Thus the most skilful Astronomers make it much larger upon other Principles *. According to M. *Cassini*, the Globe of the *Sun* is a million of times bigger than the Earth †. And since it spreads Light abroad on all sides, it must on all sides be surrounded with ethereal Matter.

2. This Globe of celestial Fire is probably a collection of ramous and gross Matter

* Ricc. Almag. T. 1. p. 294.

† Elém. de l'Astron. p. 49. Rec. d'Observ. par Mess. de l'Acad.

moved rapidly on all sides by the action of a subtile and fine Matter. For it is a Fire which very much resembles terrestrial Fire; since it enlightens, warms, sparkles, shines, and darts out Rays on all sides, as the Fire which we kindle upon the Surface of the Earth. Now terrestrial Fire is a Collection of ramous and gross Matter, hurried on all sides by the rapid Motion of subtile and fine Matter*. Therefore, &c.

But seeing the *Sun* so white, so luminous to the naked Eye, would you believe, *Aristus*, that it had its Obscurities and Spots, as *Mars* and *Jupiter* have? There are some Years which have not a Month, but what some Spots in the *Sun* are observable^a. Father *Scheiner*^b, a Jesuit, and *Galileo*, were the first who observed any.

Arist. The brightness with which this Planet shines, would not make one suspect its being covered with Shades and Obscurities.

Eudox. I saw upon the Discus of this Luminary, with a Telescope, whose Glasses were coloured, seven or eight heaps of Spots at once. In order to observe them, it is sufficient to receive the Image of the *Sun* into an obscure Room, thro' a Hole which contains a convex Glass in form of a Lens, or a Tele-

* 24 Convers. Vol. 1.

^a Hist. de l'Acad. 1719. p. 74.

^b Rosa Ursina, l. 1. Taq. Astr. l. 8. p. 344.

scope^c. They have remarked in the *Sun* forty or fifty Spots at the same time. Sometimes you would say that it is surrounded with a Girdle of Spots^d. They have seen some larger than the Earth^e. What do I say? On *December 21, 1719*, one passed Southward thro' the middle of the Discus of the *Sun*, which was found by the Members of the Royal Academy of Sciences to be more than four times bigger than the Earth^f. In 1714, they had observed one which might be 125 times bigger than the Earth^g. And in 1706, there appeared a Collection of Spots, whose intire Mass, if one suppose it spherical, ought to have been 1728 times bigger than the Earth^h. It was only an invisible Spot in the Sun.

Arist. I am no longer astonished that the *Sun* should grow pale at *Cæsar's* death. This paleness probably proceeded from seven or eight heaps of Spots diffused over the Discus of the *Sun**.

Eudox. They saw in it, in 1716, eightⁱ different Collections of Spots, without observing any diminution of its Splendour; and the Paleness with which the *Sun* was covered at

^c Ibid. l. 2.

^d Tacq. Afr. l. 8. Tract. 3. n. 7. p. 344. Hist. de l'Acad. 1719. p. 75.

^e Tacq. Afr. l. 8. p. 345.

^f Hist. de l'Ac. 1720. p. 96.

^g Hist. de l'Ac. 1719. p. 76. 1714. p. 79.

^h Hist. de l'Ac. 1706. p. 123.

ⁱ Plin. l. 2. T. 1. c. 30.

Cæsar's death, might very well have had no other subsistence but in the imagination of Flatterers.

Eudox. But why may not those apparent Spots, *Eudoxus*, be so many Planets which move like *Mercury*, round about the *Sun*?

Eudox. Planets would neither appear nor disappear suddenly toward the middle of the *Sun's* Discus, without shewing themselves toward the Circumference; since Planets are all solid and durable Bodies. Now they have often seen Spots appear, and they have also seen them disappear at once toward the middle of the *Sun's* Discus, without having been seen toward the Extremitiesⁱ.

Arist. What then are these Spots? fixt Rocks, sometimes covered with a luminous Liquid or inflamed Waves, and sometimes discovered to the Eye?

Eudox. Bodies, which sensibly change their bigness and situation in regard of one another, are not Species of fixt and permanent Rocks. Now the Spots of the *Sun* change situation and bigness^k. Some have been seen to increase so as to appear forty times larger than they appeared at first^l. These are probably new Productions, Foams floating upon

ⁱ Tacq. Astron. l. 8. Tract. 3. n. 7. Hist. de l'Ac. 1708. p. 107. 1706. p. 122. 1710. p. 111. 1705. p. 127. 1701. Mem. p. 39.

^k Le P. Taquet. Astron. l. 8. Tract. 3. n. 7. Hist. de l'Ac. 1705. p. 127. 1708. p. 107.

^l Hevelii Cometographia, l. 9. p. 711. l. 8. p. 478.

the Surface of the *Sun*. The *Sun* must bear a resemblance to an impure Liquor, which bubbles up and throws out Froth, and of the Froth which issues out of the *Sun*, must be formed opaque and black Bodies capable of stopping the Action of an infinity of Rays, of obscuring divers parts of the *Sun*'s Surface, and of presenting to our Eyes by that means divers heaps of Spots, some more obscure, and others more clear.

In short, these sorts of Froth may wander at the pleasure of inflamed Waves, augment and diminish. Hence the changes of bigness and situations in the Spots. The Froth may come out of all parts of the *Sun*, as it comes out of bubbling Liquor. Hence the Spots which one sees arise at once in divers parts of the *Sun*. The Action of the Liquid, which undermines them according to their Depth, may dissolve, and at last render them imperceptible by dissolution, and make them to pass again into the Substance of the Liquid out of which they sprung up like Froth out of a Liquor that boils. Hence the Spots disappear at once.

The Spots of the *Sun* are generally environed with a kind of Cloudiness, not so black as the Spots themselves.

Arist. Because probably the Extremities of the Spots are transparent, or are covered in part with a luminous Liquid. But have these Spots only irregular Motions ?

Eudox.

Eudox. Ordinarily we see the Spots advance from the Eastern Limb of the *Sun* toward the Western^m. And often times have they been seen to make an intire Revolution round the *Sun* in about twenty seven days and an halfⁿ.

Arist. Does the *Sun* itself then turn round upon its own Centre in twenty seven days and an half?

Eudox. The Spots of the *Sun* cannot, as they do, make a Revolution round the *Sun* in about twenty seven days and an half; that is, in twenty seven days, twelve hours, and 20' or 30', unless the *Sun* it self turned upon its own Axis in the same Space, since they float upon the Liquid of this Planet. In short, we perceive no interval between them and this Liquid. Being observed from divers parts of the Earth at the same time, they appear in the same point of the *Sun*. They find no less distance in them than in this Planet. Therefore the *Sun* turns round upon its own Axis in about twenty seven days and a half.

And it turns after such a manner, that the upper part moves from West to East, and the lower part from East to West. For we only see the inferiour part, and we see the Spots move from the Eastern border of the *Sun* toward

^m Le P. Taquet. Astron. l. 8. Tract. 3. p. 7.

ⁿ Decouv. de la Lum. cél. qui paroît dans le Zodiaque, p. 17. Recueil d'Observ. Hist. de l'Acad. 1702. p. 73. 1706. p. 122.

the Western, and afterward to return again by the Eastern. And since Spots, which pass through the Center of the *Sun*, in making their Revolution, describe a Line which makes with the Plane of the Ecliptick an Angle of seven Degrees and an half, the Equator of the *Sun*, or the Plane of a Circle, which it describes in its Revolution, must make, with the Ecliptick, an Angle of the same bigness°.

Will you tell me, *Aristus*, why the Motion of the Spots appears slower toward the extremities of the *Sun's* Discus than toward the middle?

Arist. As the *Sun* is round, and the Spots ascend in regard to us, or descend toward the Borders, they are sensibly a longer time in the same visual Rays, without producing considerable changes in the Eye. Hence their apparent slowness.

But, *Eudoxus*, could not our Eyes which have discovered what passes in the *Sun*, find something singular in the Stars?

Eudox. Another day we shall speak of the Stars. To-day let us talk of the *Dauphin*, who is the Object of our Vows. He is a new Sun, whose presence will charm the People. Let us before-hand taste the pleasure which he is going to diffuse over our Horizon.

° Scheiner. Rosa Ursina. Taquet. Astron. p. 345. M. Cassini. Découv. de la Lum. cél. &c. p. 17, 63. Rec. d'Observ. par Mess. de l'Acad. Hist. de l'Acad. 1701. p. 105.



CONVERSATION XIV.

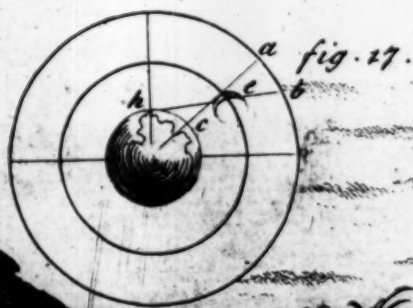
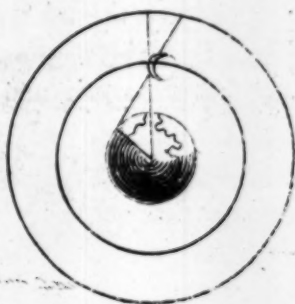
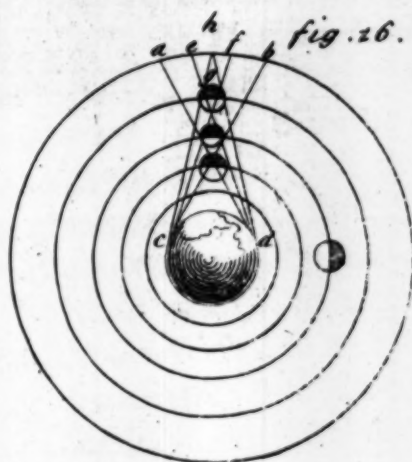
*Upon the STARS.**Eudox.*

LET us, begin, *Aristus*, with calling to mind the Revolution of the Planets and the Sun, their Distance and Bigness; and the Knowledge of the Stars will thereby be rendered the more easy.

1. According to the Observations of the most skilful modern Astronomers, the Planets which turn upon their own Axes, as the Sun, make this Revolution after the same manner; so that the upper Hemisphere moves from West to East, and the lower Hemisphere from East to West, since we see their Spots move in the lower Hemisphere from East to West, disappear in the Western Limb, and appear again in the Eastern. The Satellites have also a Direction from the West toward the East in the upper part of their Orb, and a contrary Direction in the lower*.

2. We know the distance of the Planets by the Parallax, Fig. 16. The Parallax is the

* Hist. de l'Acad. 1707. p. 93. 1716. p. 57.





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distance which we observe between two different Points of the Heaven (a, b) to which the same Object (o), seen at the same time by two Observators (c, d) is referred. The Parallax (ef) diminishes in proportion, as the Object (g) happens to be farther distant from the two Points where they make their Observations. Is the Object (h) at a certain distance? The visual Rays which come to be re-united, no longer terminate in Points sensibly separate, after they have cross'd one another in the Object. The Observators see the Object in the same part of the Heavens. The greater sensible distance there is between the Points to which they refer, the greater is the Parallax.

Arist. But pray, what Method must we use to know the distance of the Stars by their Parallax?

Eudox. Let us suppose a Star, Fig. 17. the Moon (e) for example in the Horizon, and two Lines drawn to the Center of this Star, one of which proceeds from the Center (f) of the Earth, and the other from any Point (h) of its Surface, where there is an Observer. Those two Lines or visual Rays cross one another in the Planet, and making a superiour Angle (aeb) terminate in two different Points of the Heavens. This Angle, or the distance of those two Points, (a, b), is the Parallax. The Angle (feh) opposite at the Vertex, and formed by the two Lines which cross one another

ther in the Centre of the Planet, answers to this Parallax. Those two Lines with the Semidiameter (fb) of the Earth, which is about 1500 Leagues, make a Rectangular Triangle, or which has a right Angle known; after the Angle (feb) opposite at the Vertex is known, we know two Angles. Now when we know two Angles of a Triangle, we know both the three Angles and the three Sides, and consequently the Side (cf) which is the Distance from the Center of the Earth to the Star. We know how many times this Side contains the Semidiameter (fb) of the Earth.

The Parallax varies in proportion as the Planet is more or less remote from us, they have found in the Moon about one degree of Parallax^p; five and twenty Seconds in *Mars*, and Ten Seconds in the Sun^q.

Hence expert Astronomers place the Moon at 90 thousand Leagues from the Earth*, or there-

^p Découverte de la Lum. cél. &c. p. 22. Hist. de l'Acad. 1703. p. 16.

^q Elém. d'Astron. par M. Cassini. Rec. d'Obs. Déc. de la Lum. cél. &c. p. 22. Sir Isaac Newton. Greg. Astr. p. 336. Mém. de l'Acad. 1722. p. 227. 1726. p. 99.

* Let us suppose that the Semi-diameter of the Earth seen from the Sun be 11 Seconds, as it was lately collected from the Parallax of *Mars*, observed by Dr. *Halley* and Mr. *Pound*: and then the Earth's Distance will be nearly 20000 Semidiameters of the Earth, and the Moon will be less than *Mercury*. And the Proportion of the Diameter of the Earth to the Sun will be that of 1 to 83; to which Proportion we may give our Assent, till by an Observation of *Venus* in the Sun's Body, which will happen in 1761, we may be made more certain of the Sun's Parallax.

There-

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thereabouts^r; *Mars* in Perigeon at 11 or 12 Millions of Leagues; *Venus* in Conjunction with the Sun at a distance something less^t; the Sun, at 33 Millions of Leagues^t. They allow 24 or 25 Years for a Cannon Bullet, to

Therefore the Diameter of the Sun is to the Planets Diameters, nearly in the Proportions represented in the following Table.

The Diameter of the Sun is to the Diameter of,	<i>Saturn,</i>	as 1000 is to	137
	<i>Jupiter,</i>		181
	<i>Mars,</i>		6
	<i>the Earth,</i>		12
	<i>Venus,</i>		12
	<i>Mercury,</i>		4

And because the Spheres are to one another as the Cubes of their Diameters,

The Sun will be to	<i>Saturn;</i>	as 1000000000 is to	2571353
	<i>Jupiter,</i>		5929741
	<i>Mars,</i>		216
	<i>the Earth,</i>		1728
	<i>Venus,</i>		1728
	<i>Mercury,</i>		64

Hence it follows, that the Sun is a hundred and sixteen times bigger than all the Planets put together. *Saturn* is 400 times less than the Sun: But for quantity of Matter, it is 2400 times less than the Matter of the Sun. *Jupiter* the biggest of all the Planets, is 160 times less than the Sun; and his Matter that composes his Body is 1033 times less than the Matter of the Sun. But our Earth, if it be compared with the Sun, is but of a very small Magnitude, and not bigger than a physical Point; for it is 500000 times less than it. Besides, comparing the Planets with one another, we find that *Jupiter* is bigger than all the rest of the Planets put together; and that he is above 2000 times bigger than the Earth, but *Venus* is of the same bigness with the Earth. Yet there are two of the six Planets, viz. *Mercury* and *Mars*, less than the Earth. *Keil's Astronomy*, p. 344.

^r Ricciol. Almag. T. 1. l. 6. c. 7. p. 418. n. 17. Hist. de l'Acad. 1722. p. 91.

^t Mem. del'Acad. 1722. p. 227.

^t Elém. d'Astron. par M. Cassini, p. 48. Découv. de la Lum. cél. p. 14. Hist. de l'Acad. 1706. p. 99.

go from the Earth to the Sun, or to come from the Sun to the Earth, always with the same Velocity ^u. There are some who make a Vessel to sail out of our Havens, and to arrive at some Spot of the Sun after a Navigation of eleven hundred Years at least, in an immense Fluid ^w.

Arist. This brings to my mind what *Pliny* says of a Stone, which fell down from the Sun into *Thrace* according to the Prediction of *Anaxagoras* ^x. No doubt *Anaxagoras* had seen in his Astronomical Observations, the Stone separated from the Sun some hundreds of Years before the end of its fall.

Eudox. Probably *Anaxagoras* was too great a Philosopher to make such a Prediction. However that be; what time would a Vessel require, was she the best Sailer, to come from *Jupiter* and *Saturn*, especially when they are in their Apogea, in order to bring us more certain News of those Planets than what we have? They make the Distance of *Jupiter* from the Sun five times greater than that of the Earth, and that of *Saturn* about ten times ^y; Father *Riccioli* ascribes to *Saturn* about 35 Millions of Leagues. After the most recent Observations, they make his Distance

^u M. Huygens.

^w Nieuventit, p. 449.

^x Book 2. ch. 58.

^y Kepl. Epit. Astron. l. 4. p. 455. Riccioli l. 6. c. 7. p. 418. n. 17. Mem. de l'Acad. 1706. p. 97.

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about three hundred and thirty millions of Leagues *.

From the Distance and apparent bigness of Objects, they conclude their real Bigness. The Globe of the Moon appears to be about 60 times less than that of the Earth ^a, a great Circle of which contains 9000 Leagues, as we have said elsewhere ^a, and the Semidiameter about 1500 Leagues. The Earth is also bigger than *Mercury*: but the Earth and *Venus* are almost of the same Diameter and Bigness. *Jupiter* and *Saturn*, whose Diameters are almost equal to one another ^b, are about 1000 times bigger than the Earth ^c. As for the Sun, M. *Cassini* found its Globe a Million of times bigger than the Earth ^d.

This being granted, the Stars are like so many Suns. They are, I say, so many Species of Suns, if they are Luminaries very far distant, very large and luminous of themselves †. But, 1. The Stars are luminous Bodies

* M. de l'Acad. 1716. p. 56.

^a Hist. de l'Acad. 1706. p. 109.

^a 14 Conversat. T. 1.

^b Hist. de l'Acad. 1716. p. 63.

^c Ibid.

^d 1707. p. 99.

† " That the fixed Stars are at an immense and inconceivable distance from us, may easily be collected from hence; that though by the Earth's annual Motion, we are nearer them by the whole length of the Diameter of the *magnus Orbis*, yet their situation or magnitude is not in the least altered. And indeed it cannot be determined how great this distance is; because there is no Parallax nor any other Method, whereby it can certainly be found out. Mr. *Huygens* thought of a very

Bodies very far distant; for they are infinite-
ly

"ingenious way of making a Conjecture about it in his Con-
"jectures concerning the Planetary Worlds." Book II. p. 125.
Those, says he, who have hitherto undertook to calculate their
Distance, have not been able perfectly to compass their Design, by
reason of the extreme Niceness, and almost Impossibility of the Ob-
servations requisite for their purpose. The only Method that I see re-
maining to come at any tolerable probability in so difficult a Case,
I shall here make use of. Seeing then that the Stars, as I said
before, are so many Suns, if we do but suppose one of them equal to
ours, it will follow, that its Distance from us, is as much greater
than that of the Sun, as its apparent Diameter is less than the
Diameter of the Sun. But the Stars, even those of the first Mag-
nitude, though viewed through a Telescope, are so very small,
that they seem only like so many shining Points, without any per-
ceivable Breadth, so that such Observations can here do us no good.
When I saw this would not succeed, I studied by what way I could
so lessen the Diameter of the Sun, as to make it not appear
larger than the Dog, or any other of the chief Stars. To this pur-
pose I closed one end of my twelve-foot Tube with a very thin Plate,
in the middle of which I made a Hole not exceeding the twelfth part
of a Line, that is, the hundred and forty-fourth part of an Inch. That
end I turn'd to the Sun, placing my Eye at the other, and I could see
so much of the Sun, as was in Diameter about the 182d part of the
whole. But still that little Piece of him was much brighter than
the Dog-star is in the clearest Night. I saw that this would not do,
but that I must lessen the Diameter of the Sun a great deal more.
I made then such another Hole in a Plate, and against it I
placed a little round Glass that I had made use of in my Micro-
scopes, of much about the same Diameter with the former Hole.
Then looking again towards the Sun, (taking care that no Light
might come near my Eye to hinder my Observation) I found it ap-
pear of much the same clearness as Sirius. But computing accord-
ing to the Rules of Dioptricks, I found his Diameter now was but
 $\frac{1}{182}$ part of that hundred and eighty second part of his whole Dia-
meter which I saw thorough the former Hole. Multiplying $\frac{1}{182}$
and $\frac{1}{182}$ into one another, the Product I found to be $\frac{1}{27664}$. The
Sun therefore being contracted into such a Compass, or being removed
so far from us (for it's the same thing) as to make his Diameter but
the 27664th part of that we every day see, will send us just the
same Light as the Dog-star now doth: And his Distance then from
us will be to his present Distance undoubtedly, as 27664 is to 1; and
his Diameter a little above four Thirds. 4¹¹. Seeing then Sirius

ly beyond *Saturn*, since not only *Saturn*,
whose

is supposed equal to the Sun, it follows that his Diameter is likewise 4^{111} , and that his Distance to the Distance of the Sun from us is as 27664 to 1. And what an incredible Distance that is, will appear by the same way of reasoning that we used in measuring that of the Sun. For if twenty five Years are required for a Bullet out of a Cannon with its utmost swiftness, to travel from the Sun to us, then by multiplying the Number 27664 into 25, we shall find that such a Bullet would spend almost seven hundred thousand Years in its Journey between us and the nearest of the fixed Stars. And yet when in a clear Night we look upon them, we cannot think them above some few Miles over our Heads. What I have here enquired into, is concerning the nearest of them. For the other; since, it was before observed, they are so much farther removed into the Heavens, that the Distance of the nearest from the following ones, is as great as the Distance of those from the Sun, what an Immensity must there still remain?—When I have been reflecting thus with myself, I thought all our Arithmetick was nothing, and that we are versed but in the Rudiments of Numbers in comparison of this great Sum. This is indeed a very ingenious Conjecture of Mr. Huygens. But our Flamsteed has at last found, by wonderful diligent Observations, that the fixed Stars have an annual Parallax, which is a compleat Demonstration of the Motion of the Earth. And that this Parallax is about $3c^{11}$.

But the following Particulars, which are worth Observation, are so many Consequences of the vast Distance of the fixed Stars.

First, If we were to approach ninety nine times nearer to the fixed Stars than we now are, so that we were distant from them but a hundredth part of the present Distance, we should see them but a very little bigger than we do now; for they would appear no bigger, nor no otherwise than they do now, when looked at with a Telescope which magnifies the Object a hundred times.

Secondly, Nine parts at least in Ten of that whole Space which is betwixt us and the fixed Stars, receive no more Light either from the Sun or from any of the fixed Stars, than we do from the Stars in a clear Night.

Thirdly, Light, (because it is propagated from the Sun to the Earth, according to some in seven, and according to others in ten Minutes of time) cannot come from the fixed Stars to us in less than forty days time at the least; and Sound could not come from thence to us in less time than fifty thousand years;

whose Distance from the Earth is about 300 Millions of Leagues, eclipses them, but the Telescope which magnifies the apparent Discus

and a Ball shot out of a Cannon, would take up much longer time still. See *Miscel. Curios.* Vol. I. p. 277. And from hence the famous Mr. *Whiston* draws a very ingenious Argument, which overthrows both the *Ptolemaick* and *Tychonick* Systems of the World. "It, says he, there be any difference in the Distances of the fixed Stars from us, and none of the *Ptolemaick* Astronomers have ventured peremptorily to affirm that there is not; then by reason of their vast Distances, the time which Light takes up in coming from a fixed Star to the Earth, must be very great, not to be measured by a few Hours or Days, but by whole Weeks or rather Months. Whence it will follow, that the true places of the fixed Stars, though they are both really and apparently in their proper Parallels of Declination; yet with respect to their right Ascensions, will very much differ from their apparent places, nor will any one of them, unless by great chance, ever be in that place, with respect to the Horizon or Meridian of the Earth where it appears to be. And besides, it will follow from the difference of Distances, that the real Order and Situation of the fixed Stars, with regard to each other, is not such as we see it from the Earth. We do indeed certainly know by Observation, the particular Parallel which any of them is in, because the successive propagation of Light does not at all disturb their situation sideways; but what their places are, with respect to each other in any parallel, cannot at all be known by Observation, unless we knew their Distances, and considered well what time Light would take to pass through them, (which at present we do not.) Now since we know the places of the fixed Stars according to their Longitude and Latitude, only by having their places with respect to their right Ascension and Declination given by Observation; it will certainly follow, that the real places of the fixed Stars can never be at all determined by us, the successive motion of Light hindering it. Which strange, or rather whimsical thing, in the ancient Hypothesis, has not been observed by any body (that I know of;) but I think it is very well worth the notice of the Followers of *Ptolemy* (if there remain any such.) Wherefore I leave so strange, and such an inartificial Invention to be considered by them, and despised by you. *Astron. Lect.* p. 233.

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of *Saturn*, 200 times^e, diminishes them instead of augmenting them, robbing them of their deceitful Ornament of Rays and Sparkling, and leaving them only, even such of them as have the most apparent Bigness, a Diameter of some Seconds^f: So that we imagine the Distance of the Dog-star from the Earth, to be at least 43700 times greater than that of the Earth from the Sun^g. 2. The Stars are very great Luminaries, since they are still perceivable notwithstanding their enormous Distance. 3. The Stars are Bodies luminous of themselves; for in a word, notwithstanding their excessive Distance, we see them sparkle and send forth Rays. Bodies which only reflected Light, would neither have Scintillation nor Radiation, at so prodigious a Distance. *Saturn*, which is only 300 millions of Leagues distant at most, neither sparkles nor sends forth Rays. Nor does the Moon, which is only distant from us about 90000 Leagues. Therefore the Stars are like so many Suns.

Arist. Is the Heaven then bestrewed with an infinity of Suns?

Eudox. In that we are deceived. When we lift up our Eyes towards the Heaven in the Evening, we think that we see an infinite number of Stars, altho' with the naked Eye, skilful Astronomers have observed but 14 or

^e Mem. de l'Acad. 1717. p. 63.

^f Ibid. p. 65.

^g Ibid. 1720. p. 91.

15 hundred at most. When we turn our Eyes from one to another, the Impression of the first still subsists, sometimes the very moment that we look upon the others. Thence the Illusion. But with a Glass we see innumerable Stars, we discover more than 2000 in such a Constellation ^h.

A Constellation is a Collection, or certain Number of Stars; they count about 62 or 63 Constellations in the Heavens.

A Celestial Globe will sooner teach you, or sooner bring to your mind the Celestial Sphere, the Names and Situation of the different Constellations.

Arist. But, *Eudoxus*, why do we see more Stars upon the North-side than Southward ⁱ? Should not the Earth be in the middle of the World? Should it be nearer the South-Pole ^k.

Eudox. The truth is, the South part has more Stars distinguish'd by their Splendour.

Arist. The Immobility of the Stars charms me as much as their Splendour. I admire this Spectacle continually uniform in the immense Regions, which hold the Stars as it were suspended.

Eudox. What, on the contrary, surprizes and charms Astronomers, is to perceive prodigious changes in Spaces, which seem exempted from

^h Dans l'Orion. Reitha. p. 197. Rarii Sydereo-Mystici. Ric. Almag. l. 5. c. 6. p. 413.

ⁱ Ric. Alm. l. 6. c. 6. p. 413.

^k Traité de la Pesanteur, par le P. Castel. T. 1. p. 138.

change. When we observe changes in those Countreys, they ought to be enormous, however small they may appear by reason of their immense Distance; and Astronomers discover some considerable ones. Some Stars disappear, which the Ancients have seen. Some time ago they counted seven Stars in the *Pleiades*, and now we observe but six with the naked Eye. Some new ones appear. *Hyparchus* observed a new one 150 Years before the Birth of *Jesus Christ*. They saw one almost as big as *Venus* in *Cassiopea* in 1572, which disappeared without returning in 1574. The Years 1600 and 1604 presented such like Spectacles to the Eyes ¹. There are some Stars which disappear and appear again, sometimes bigger, sometimes smaller ^m; some in very regular Periods, as the Star of *Balæna*, which is only visible four Months and a half at most in one of its Revolutions, and whose Revolution is in about eleven Months; that of *Cygnus*, whose Revolution is in thirteen Months; and that of *Hydra*, whose Revolution is in two Years ⁿ, and which is seen but about four Months during all that time ^o. There are scarcely any Constellations in which some sensible change does not happen in the space of an hundred Years; and if any happen, it is especially

¹ Hevelii Cometographia, l. 7. p. 374. Le P. Taquet. I. Astron. l. 8. Traët. 2. c. 1. de notis Stellis, n. 2, p. 332.

^m Hist. de l'Acad. 1719. Mem. p. 95.

ⁿ Hist. de l'Acad. 1706. p. 111.

^o 1709. p. 81.

in the Milky Way, which is only a prodigious Collection of Stars ^p.

Arist. But how can it be that antient Stars disappear, and new ones appear, and that the same Stars appear and disappear in very regular Revolutions ?

Eudox. Froths and Spots yet larger than those of the Sun, formed of sulphurous and nitrous Materials, and spread over the Surface of the Stars, may incrustate them, and hinder the inflamed Liquid from darting forth its Rays so far as our Eyes ; and this is a disappearing of the Stars. The inflamed, but incruited Liquid, may undermine gradually by its continual agitation the Spots or Crusts, and dissipate them, or diffuse it self over them ; and this is a new Appearance of Stars*. Finally, some Stars, may be only Half-suns composed of a solid and obscure part, and of a liquid and luminous part, according to the ingenious Hypothesis

^p Galilée in Nuncio Sydereo. Riccioli. T. 1. l. 6. p. 412.

* The Appearance of new Stars (says Dr. Clarke) is much better accounted for from the Theory of Comets. For tho' some of the fixed Stars may be so very remote from us, as not to be seen by the help of our best Glasses, yet as they are fiery Bodies like the Sun, if any new Matter or Fewel be added to them, they may on a sudden blaze out, so as to be seen by the naked Eye, brighter than any other Star ; and as this Fewel is devoured, they may diminish in their Brightness, and by degrees return to their first invisible State. And that Comets might probably supply them with this Fewel ; see Sir Isaac Newton's Princip. Book III. p. 481. The Comet which appeared in 1680 in its Perihelion, was not so far distant from the Sun, as the sixth part of the Sun's Diameter, and by reason of its very great Velocity in this nearness, and some Density that there is in the Sun's Atmosphere,

thesis of M. *Bouillau*⁹. A Star of this Species turning upon its own Axis, presents to our eyes sometimes the luminous part which renders it visible, and sometimes the solid obscure part which renders it invisible to us; and this is the successive appearance and disappearance of a Star in its Revolution. A Star is a longer or shorter time visible or invisible, proportionally as the luminous part is larger or smaller than the obscure part. Why in the Stars of *Hydra* and *Balæna* is the time of its being visible shorter than that of the contrary? Because the obscure part is bigger than the other. Moreover the obscure part may be composed of Spots, some of which are permanent, and others moveable; so that these sometimes approach to, and sometimes remove from the other. The luminous Liquid may have irregular Motions, possessing an extension sometimes greater, sometimes less upon the Surface of the Star. Hence the Changes of the bigness and duration in the Appearance of Stars.

mosphere, it must meet with some Resistance, and be a little retarded and approach nearer the Sun; and by approaching in this manner nearer and nearer to the Sun every Revolution, it must at last fall into the Body of the Sun. And in its Aphelion, where it moves slowest, it may sometimes be retarded by the Attraction of other Comets, and at some time or other fall into the Sun. And so the fix'd Stars likewise, which by degrees waste themselves by sending forth Light and Vapours, may be supplied by Comets falling into them; and by the kindling of this new Fewel in them, they may be taken for new Stars.

⁹ Bulliadi Monita duo. Journ. des Scav. 1667. p. 11.

Stars appear less big and less numerous in a Summer Night, than in Winter.

Arist. Because the Nights being darker in Winter, as the Sun is more sunk below the Horizon, the Light of the Stars is less weakened by that of the Sun.

Eudox. Thus far we have endeavoured to penetrate into the Nature and Properties of the principal parts of the Universe. Let us now endeavour to discover their arrangement, that is to say, the true System of the World.



CON-



CONVERSATION XV.

Upon the Systems of the World.

Arist. **T**O attempt to discover the true System of the World, seems, *Eudoxus*, to be a fine, but difficult Enterprize; since the infinite Wisdom of the Creator may produce the same Effects from different Causes.

Eudox. Let us recollect, *Aristus*, the most famous Systems; and in searching out the true one, we shall perhaps find at least the most probable. But that we may the more certainly find it, let us begin with examining if there be any Vortices in the Universe. They call a Vortex * a liquid Mass, whose parts are carried round a common Center.

Arist.

* That the Vortexes of Matter in which the Planets swim, are mere Fictions, and contrary to the Phænomena of Nature; is evident from the following Arguments.

First, The immense Space of the World is so far from being full of Matter (which imaginary Plenum is the sole Foundation of the Fiction of Vortexes) that on the contrary, that Space which is filled with Matter, bears no proportion at all, to that immense Space which is void of all Matter. *Clark's Rohault.* Vol. I. p. 27.

Secondly, It is evident from the Motion of Comets, which pass very freely in the heavenly Spaces all ways, and from and
to

Arist. For my part, I do not doubt, but that the *Earth, Sun, Jupiter and Saturn* have each of them their Vortex. Every one of these Bodies cannot be surrounded with a Fluid which turns round it as upon its Center without having its Vortex; since a Fluid whose parts all turn round a common Center, is a Vortex. Now, every one of these Bodies is environ'd with a Fluid which turns round it, as upon its Center. For it is certain that the Moon turns round the Earth, as upon its Center. *Mercury and Venus* after the same manner turn round the Sun; the Satellites of *Jupiter,*

to all parts (in Orbs which cut the Planets Orbs at all Angles) that the Planets cannot be carried along by Vortices of Matter.

Thirdly, According to the Laws of Astronomy, a Body which revolves in an *Excentrick Orb*, moves slower in its *Aphelion*, and quicker in its *Perihelion*; but according to the Laws of Mechanicks, the Matter of the Vortex ought to move swifter where the place is straiter and more *compressed*, that is in the *Aphelion*, than where the place is wider and *less compressed*, that is in the *Perihelion*; which two things contradict each other. Thus in the beginning of the Sign *Virgo*, where the Aphelion of *Mars* now is, the Distance betwixt the Orbs of *Mars* and *Venus*, is to the Distance between the same Orb in the Beginning of the Sign *Pisces* in the proportion of three to two very nearly: And therefore the Matter of the Vortex contained between those two Orbs, ought to move swifter in the Beginning of *Pisces*, than in the Beginning of *Virgo*, in the same Proportion of three to two; for the straiter the Space is, through which the same Quantity of Matter passes in the same time of one Revolution, with so much the greater Velocity ought it to pass. If therefore the Earth were carried along in this Celestial Matter, being relatively at Rest with it, and revolved together with it about the Sun; its Velocity in the Beginning of *Pisces*, would be to its Velocity in the Beginning of *Virgo*, in a sesqui-alterate Ratio: whence the apparent Diurnal Motion of the Sun in the Beginning of *Virgo*, would be more than seventy Minutes, and in the Beginning

piter, round *Jupiter*; those of *Saturn*, round their primary Planet ^a; and every one of those Luminaries swim in a Fluid, which turns round as they do. Every one of them swims in a Fluid, since they all remit the Light to our Eyes, and Light is a fluid Body. The Fluid in which these Stars are carried, turns round as they do. Otherwise they must incessantly communicate of their Motion to divide it, they would lose it proportionally, and consequently their Motion would become slower. It never does grow slower: Therefore the *Earth*, *Sun*, *Jupiter*, and *Saturn* have each of them their Vortex.

Beginning of *Pisces* less than forty eight Minutes. Whereas we find, by experience, the apparent Motion of the Sun is greater in the beginning of *Pisces*, than in the beginning of *Virgo*, and therefore the Earth moves swifter in the beginning of *Virgo*, than in the beginning of *Pisces*. The Hypothesis therefore of Vortexes directly contradicts the Astronomical Phenomena, and tends more to confound the Celestial Motions than to explain them. See *Newt. Princip. Book II. Schol. 10. Prop. LIII.*

Fourthly, If three equal round Vessels be filled, the one with Water, the other with Oil, the third with molten Pitch, and the Liquors be stirred about alike to give them a vortical Motion; the Pitch by its Tenacity will lose its Motion quickly; the Oil being less tenacious, will keep it longer; and the Water being least tenacious, will keep it longest, but yet will lose it in a short time. Whence it is easy to understand, that if many contiguous Vortices of molten Pitch, were each of them as large as those which some suppose to revolve about the Sun and fix'd Stars, yet these, and all their parts, would by their Tenacity and Stiffness, communicate their Motion to one another, till they all rested among themselves. Vortices of Oil or Water, or some fluid Matter, might continue longer in Motion; but unless the Matter were void of all Tenacity and Attrition of Parts, and Communication of Motion (which is not to be supposed) the Motion would constantly decay. *Opticks, p. 374.*

^a 13 *Convers. Vol. III. p. 194.*

Is it not also probable enough, that the Stars, or at least some Stars, have likewise their Vortices? for in a word, 1. We discern their Scintillation at an immense distance; and the Revolution of luminous Bodies upon their Center, successively offering to our Eyes different parts, sometimes more luminous, and sometimes less bright, ought to contribute very much to render their Radiation sensible*. 2. The various Phases and Revolutions of the Stars of *Hydra*, *Cygnus* and *Balena* are sufficient Proofs that they turn upon their own Axes. And can they turn round after that manner, unless the Fluid which surrounds them turn about in like manner? Therefore it is probable enough that the Stars, at least some of them, have also their Vortices.

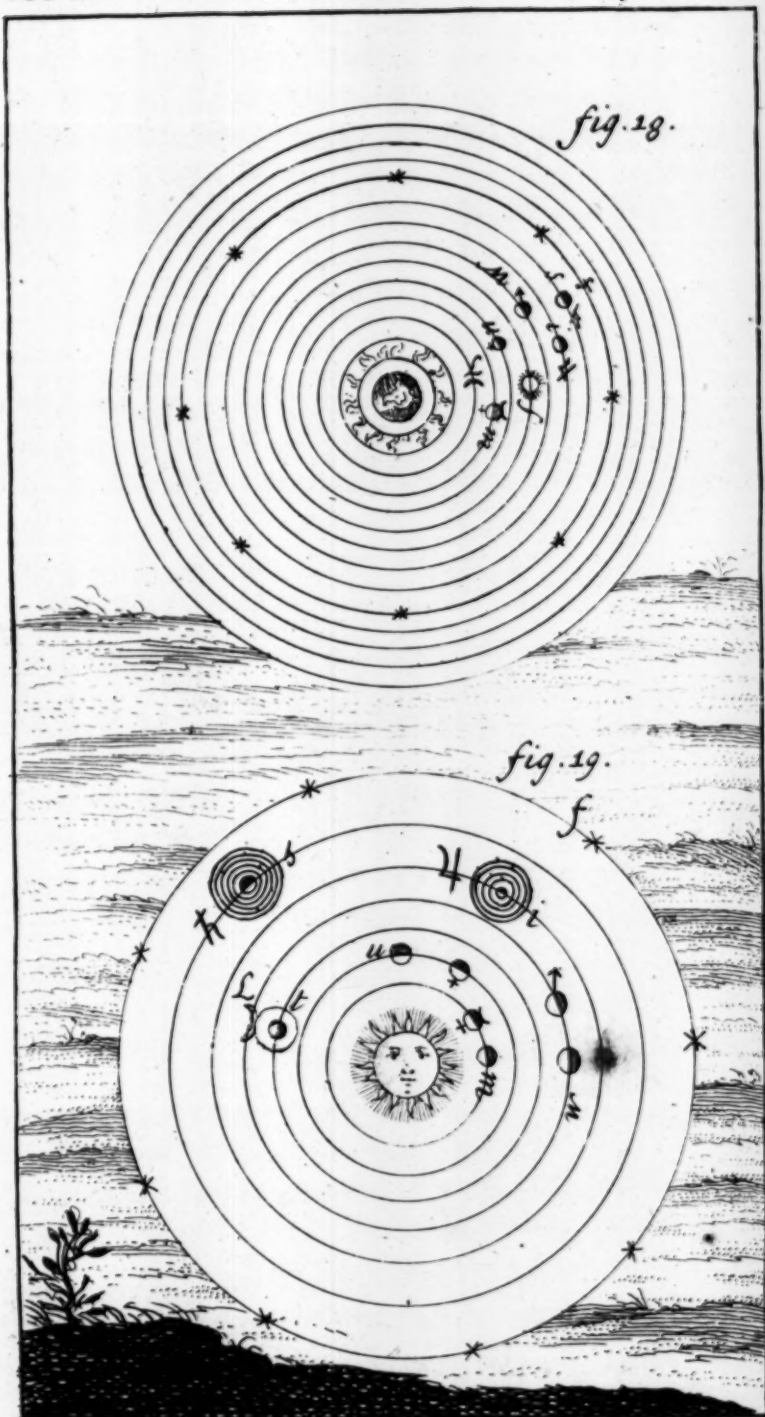
Eudox. Notwithstanding your Reasons, *Aristus*, many Persons will probably still believe that those Vortices have scarcely any existence but in the Imagination.

Arist. However that be, *Eudoxus*, do you oblige us at present with a short Description of the most famous Systems.

Eudox. These are the Systems of *Ptolemy*, *Copernicus* and *Tycho*.

Ptolemy placed the Earth in the Center of the World, and made to turn round it, in so many concentric Circles, and in this Order, beginning with the Planet nearest the *Earth*(*t*) Fig. 18. the *Moon* (*l*), *Mercury* (*m*), *Venus* (*u*),

* Riccioli Almag. T. 1. l. 6. p. 397.



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the *Sun* (*S*), *Mars* (*M*), *Jupiter* (*i*), *Saturn* (*s*), the *Firmament* (*f*).

Arist. A System, in which *Mercury* and *Venus* have not the Sun for the Center of their Motion, cannot be supported; for we see those Planets sometimes below the Sun, and sometimes above it, and sometimes in a mean Distance, without *Mercury's* being at any time distant from the Sun above 28 Degrees, or *Venus* above 48; as we have already said *. Now in the System of *Ptolemy*, *Mercury* and *Venus* have not the Sun for the Center of their Motion, since they are placed in inferior Orbits. Therefore *Ptolemy's* System is insupportable.

Eudox. Accordingly, *Copernicus* could not bear with it; and not only did he make *Mercury* and *Venus* turn round the Sun, but presumed also to transpose the Earth and Sun, to place the Sun in the Center of the World, and the Earth in the place of the Sun among the Planets, to make a Planet of the Earth, and a fixt Star of the Sun. For according to the System of this illustrious Astronomer, the Sun (*S*) is immoveable, or without any progressive Motion in the Center of the World; and the Planets revolve about this Luminary, in this Order, Fig. 19. *Mercury* (*m*); *Venus* (*u*); the Earth (*t*) in an Ecliptick with the Moon (*l*) carried about, as a Satelles, in the Vortex of the Earth; *Mars* (*M*); *Jupiter* (*i*);

* 12 Convers. Vol. III.

Saturn (*s*). The Firmament (*f*), which encloses them, has only an appearance from East to West.

The Center of the Sun, and the Center of the Earth are always in the Ecliptick, or the Earth has two Motions, one annual round the Sun, and the other diurnal upon its own Axis; so that the Equator of the Earth makes with the Plane of the Ecliptick, or the Axis of the Earth with the Axis of the Ecliptick, an Angle of $23^{\circ} 30'$.

Descartes, and the new Philosophers, have improv'd the System of *Copernicus*. In the improv'd System, if the Sun is not in the Center of the World, he is at least in the Center, or near the Center of his Vortex, to which he communicates Agitation, Fig. 20. The Planets carried along by the Motion of the Vortex are therein elevated more or less in proportion to their bigness, or solidity, their centrifugal Force; and accomplish their Circuits in more or less time, according as they are greater or smaller.

Arist. The Earth is a little degraded in this System; but it appears simple and natural.

Eudox. *Tycho* quickly avenged the Earth by replacing it in the Center of the World, and remitting the Sun to the Order of the Planets. Nevertheless he left him *Mercury* and *Venus* for Satellites. Therefore this Astronomer's System places the Earth (*t*), Fig. 21. in the Center of the World, and makes to revolve round

fig. 20.

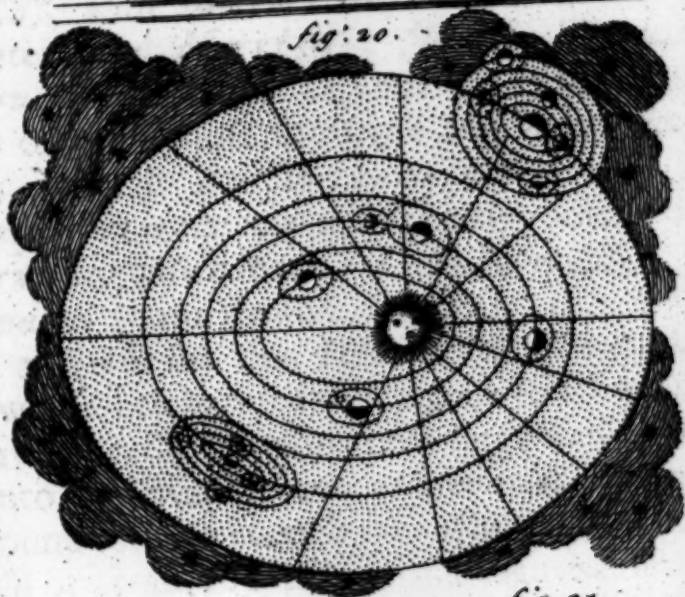
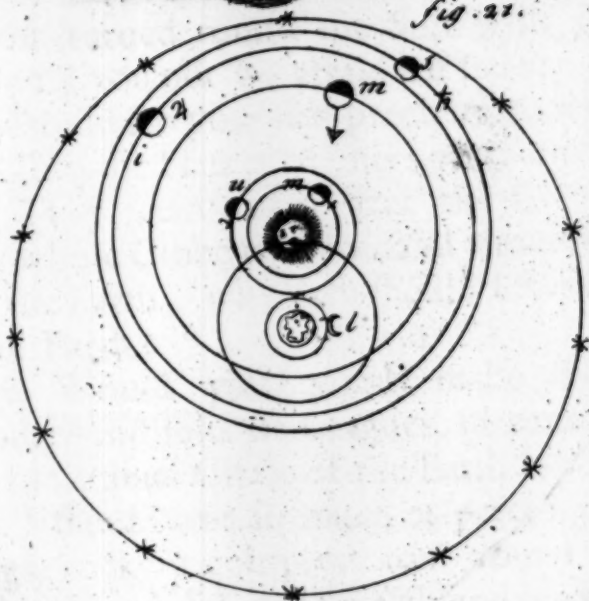
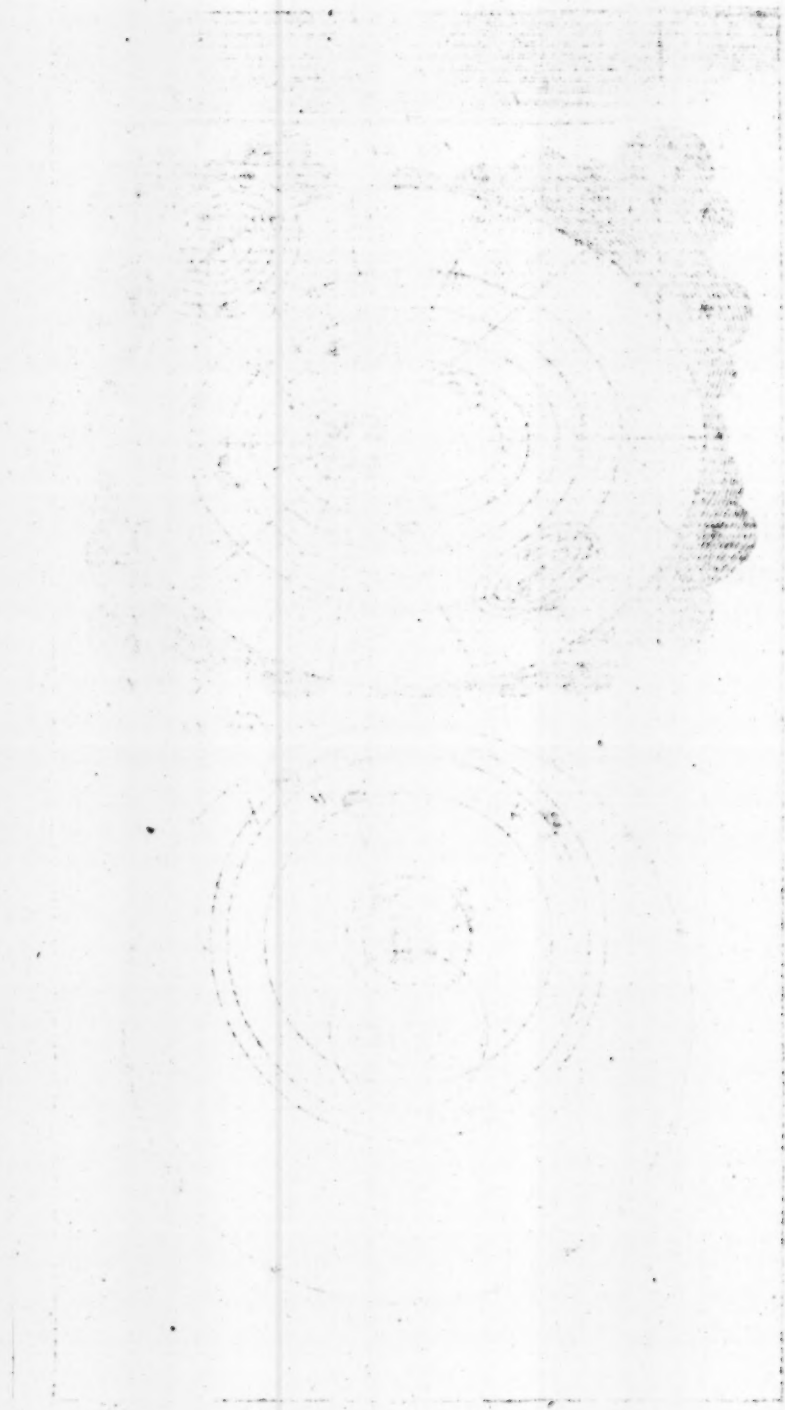


fig. 21.





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round it, in this Order, the Moon (*l*); the Sun (*S*), with *Mercury* (*m*), and *Venus* (*u*), his Satellites; *Mars* (*M*); *Jupiter* (*i*), and *Saturn* (*s*), encompassed with the Firmament (*f*), or with those immense and liquid Regions, wherein the Stars seem suspended.

Arist. But what was it in the Hypothesis of *Copernicus*, which shock'd *Tycho* so much?

Eudox. I am sensible, *Aristus*, that you have a Taste for this Hypothesis. Probably you would be charmed to see your self carried upon the Earth, as upon some large Vessel, to sail into those vast Spaces, and to make a Circle round the Sun every Year, whose Diameter would be about 66 Millions of Leagues at least. But if you turned round the Sun with the Earth, would you not be afraid lest sooner or later you should see your self precipitated with the Earth into the Flames of this Luminary?

Arist. They seem not to fear the fall of *Jupiter*, whose Globe is a thousand times bigger than the Earth; why then should I fear the fall of the Earth?

Eudox. Would you quietly make about two hundred millions of Leagues, in running through the annual Circle of the Earth?

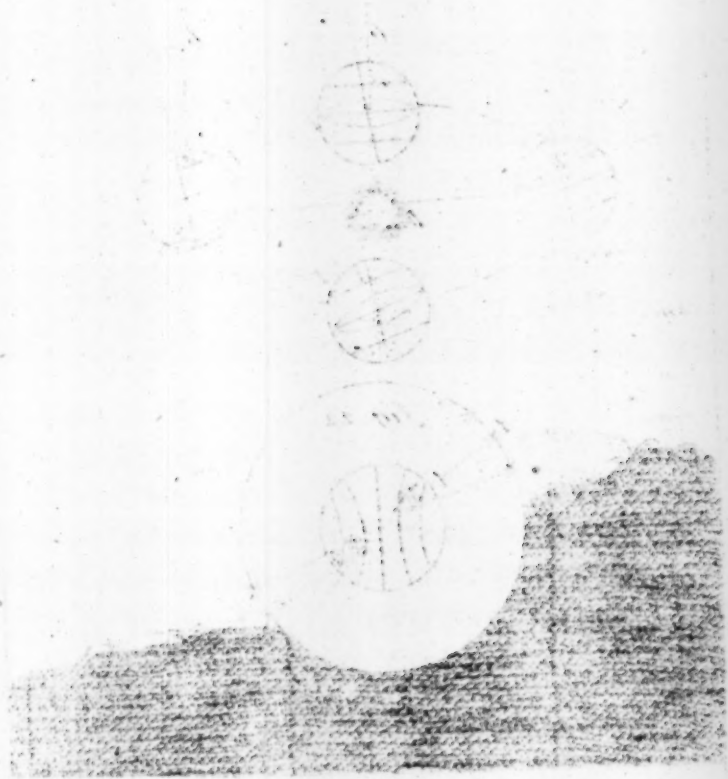
Arist. I should not so much as perceive it. One might make a compleat tour round the Earth aboard a Vessel, without observing one's circular Motion; because the same parts of the Vessel always present, and the Resemblance of the parts of the Water, would

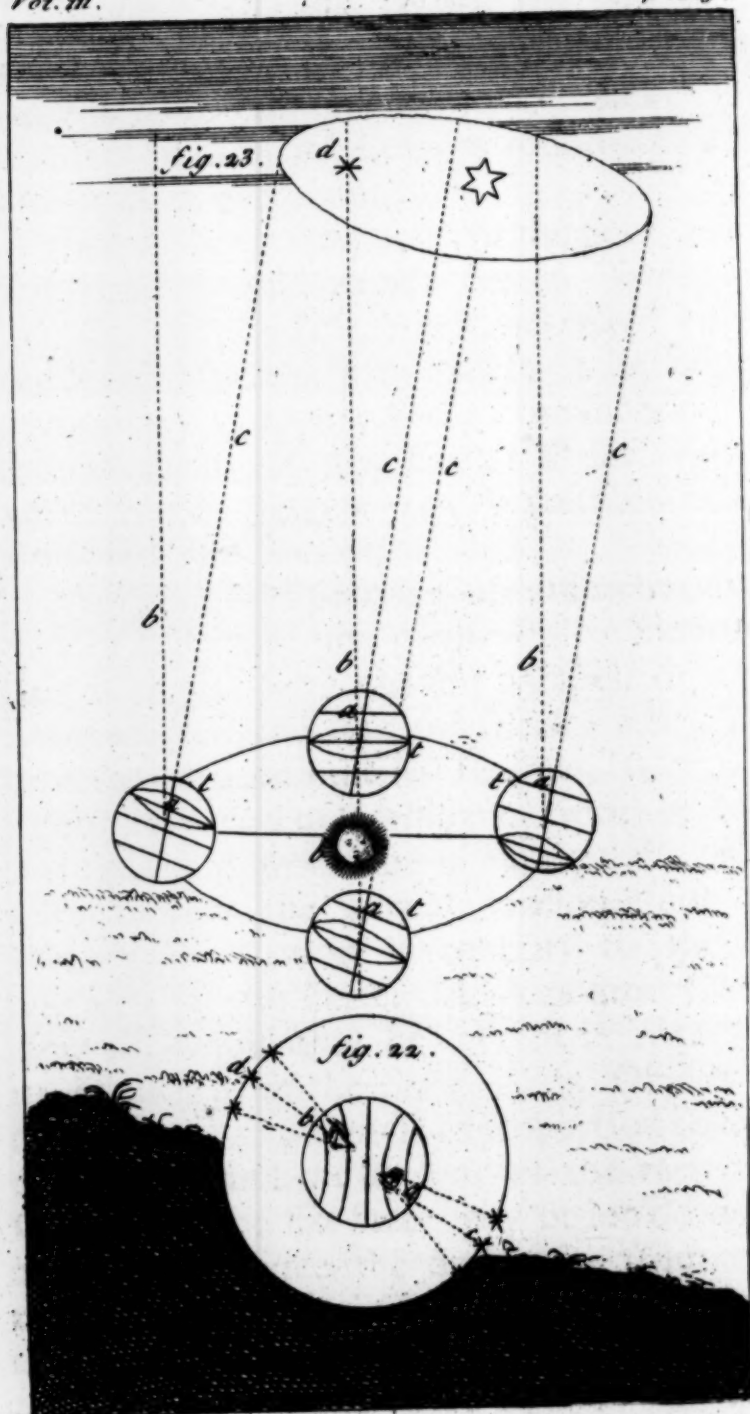
make no sensible change in the Eye. By the same reason one might quietly make two hundred millions of Leagues round about the Sun without perceiving it.

Eudox. Some new Stars, or the same, which sometimes would appear larger, sometimes smaller, and the Pole sometimes more, sometimes less elevated with respect to us, in proportion as you approached to the superiour or inferiour part of the Earth's Orbit, would make you to observe your Revolution round about the Sun.

Arist. I should perceive no difference, neither in the Stars, nor in the Pole, supposing that the Earth were entirely parallel, or nearly so to it self, and that the Circle, whose Diameter was 66 millions of Leagues, were only a Point in regard of its distance from the Stars. But the Earth would be always parallel to it self; neither the annual Motion, nor the velocity of Motion is contrary to the Parallelism of the Earth. And its great Circle, after all, would only be a Point in regard of its distance from the Stars. For, Objects diminish in relative bigness in proportion to their distance *; and the distance of the terrestrial Orbit from the fixt Stars may be look'd upon as immense, since the Stars, far from augmenting, diminish in bigness by Glasses, and the most skilful Astronomers are inclined to place the Dog-star at more than 40 thousand

* 20 Convers. Vol. II.





times 33 million of Leagues from hence. Therefore, I should see no difference either in the Pole, or in the Stars.

Eudox. Two Men in the two temperate Zones of the Earth see different Vertical Stars, and very far distant from one another. They see, the one the North-Pole, and the other the South-Pole. And in two Points diametrically opposite, of a Circle whose Diameter was 66 millions of Leagues, at 66 millions of Leagues distance from yourself, would you always see both the same Stars and the same Pole?

Arist. The visual Rays (*a b*) Fig. 22. of those two Men placed in opposite Zones, far from being parallel, when they view the Heavens, are very diverging, because of the curvature of the Earth; they diverge still more and more, and terminate in places (*c, d*) of the Heaven very remote from one another. On the contrary, as I should be always at the same place (*a*) Fig. 23. of the Earth's Surface (*t*), in opposite Points of its Circle, my visual Rays (*b*) would always be parallel to one another, the Axis (*c*) of the Earth being always parallel to itself. And consequently they would at last be sensibly re-united at the same sensible Point (*d*) of the Heaven, like two Rows of Trees of a long Avenue, which tho' parallel seem at last to be united; because the Angle of Vision formed by the visual Rays, which terminate at the Extremities of the Avenue, proceeding

ceeding continually in diminishing, in proportion as the distance of the Object augments, becomes at last nothing, or imperceptible *. Therefore the two Men would see different Stars and different Poles; and I should every where see the same Pole, and the same vertical Stars. Every where should I see the same Luminaries roll over my head.

Eudox. I know not whether you could explain, according to this Principle, the appearance of the diurnal Motion of the Stars, Planets, and Sun, from East to West.

Arist. When you go on board a Vessel from the West toward the East, you would say that the Banks, Trees and Rocks advanced from the East toward the West, because they successively present new parts to your Eyes, which paint themselves successively in divers parts of your Organs; so that at first they are referred toward the East, according to the Rules of Opticks, and after that, toward the West. By the same principle, if the Earth in 24 hours makes a Revolution upon its own Axis from West to East by its diurnal Motion, we ought to observe in the immoveable or much slower Stars, the appearance of a contrary Motion.

Eudox. If the Earth revolved upon its own Axis after that manner, and consequently we made daily upon our Axis 9000 Leagues, ought we not to be sensible of it?

* 20 Convers. Vol. II.

Arist.

Arist. We might, as we have already remarked, go round the Earth in a Vessel, without observing the Progression of the Vessel; because the continual presence of the same Vessel, surrounded with similar parts of Water, make no changes in the Eye capable of informing us thereof. Why should we perceive the Motion of the Earth, since it would always strike the Senses after the same manner?

Eudox. I see very well upon this Principle the vicissitudes of Day and Night. In proportion as the Earth in its Revolution of 24 Hours presented to the Sun successively one Hemisphere, it would withdraw the other. The Light would be diffused upon the Hemisphere, which faced the Sun; and the other would be covered with Darkness. Hence, Day and Night. But how shall we find the different Seasons in this Hypothesis?

Arist. As the Center (*t*) of the Earth is always in the Ecliptick (*abcd*) Fig. 24. as well as the Center of the Sun (*e*), and the Plane of the Ecliptick cuts the Equator (*f*) of the Earth in two opposite Points, and passes thro' the two terrestrial Tropics (*gh*), the Line or the Ray (*i*), which comes from the Center of the Sun to that of the Earth in its continual Revolution, twice encounters the terrestrial Equator (*f*), upon the Surface of the Earth; and this is the Time of the Equinoxes, and the beginning of Spring or Autumn; of the Spring, when the direct Ray ought to ap-

proach us; and of Autumn, when this Ray ought to remove from us. It reaches the Tropic of *Cancer* (*g*) once, and this is the Summer Solstice, or the beginning of Summer in regard of us, since this Ray can come no nearer to us; once the Tropic of *Capricorn* (*k*), and this is the Winter Solstice, or the beginning of Winter with respect to us, since this Ray can remove no farther from us.

Eudox. You will also find, no doubt, in the unequal Revolutions of the Planets round the Sun, their Directions, Stations, and Retrogradations; and these will only be Appearances.

Arist. They say that the Planets are *Direct*, when we see them advance from the West toward the East, according to the Order of the Signs of the Zodiack; *Stationary*, when they seem to stay in the same part of the Heavens; *Retrograde*, when they appear to retire toward the West. Now, this may happen from the inequality of their Velocity. They run thro' their Orbits in unequal times. This inequality is the Cause why the Earth passes more frequently, or more rarely between the Sun and the superiour Planets, during their Revolution, and why the inferiour Planets, namely *Mercury* and *Venus*, pass more frequently or more rarely between the Earth and the Sun. Wherefore, 1. The Earth follows, overtakes, and precedes the superiour Planets (*a b*) Fig. 25. If the Earth (*t*) follows a Planet (*d*), the Planet appears *direct*. Does the Earth (*c*) overtake a Planet

net (*d*)? The Planet appears *stationary*; because the excess of Velocity, which happens in the Earth, renders the Motion of the Planet imperceptible toward the same place, and makes the Eye refer it for some time to the same place (*f*) of the Heaven. Does the Earth (*e*) precede the Planet (*d*) considerably? The Eyes refer the Planet to a more remote part of the Heavens (*g*), and it seems *retrograde*. 2. We see those Appearances in the superiour Planets, because they compleat their Orbits more slowly than the Earth. They observe those Appearances in the inferiour Planets, because they make their Revolutions round the Sun more swiftly than the Earth. By reason of this excess of Velocity, sometimes they go before the Earth from West to East, and appear *direct*. Sometimes they are in Conjunction in the same Line with regard to some Sign, going toward the same part; and they seem *stationary*. Sometimes in the inferiour part of their Circle, they pass again from East to West, leaving the Earth very far behind them, and they are *retrograde*. Hence, the different Appearance of *Directions*, *Stations*, and *Retrogradations*.

Eudox. These Appearances are more frequent in a Revolution of *Saturn*, than in one of *Jupiter*, and in one of *Jupiter* than in one of *Mars*.

Arist. As the Earth makes a Revolution in a Year, *Mars* in two, *Jupiter* in twelve, *Saturn* in thirty, and consequently *Saturn* has less

less relative Motion than *Jupiter*; *Jupiter* than *Mars*; and *Mars* than the *Earth*; the *Earth* overtakes and precedes *Saturn* oftner in a Revolution than *Jupiter*; and *Jupiter* than *Mars*. Hence the Appearances of *Retrogradations* are more frequent in *Saturn* than in *Jupiter*, and in *Jupiter* than *Mars*.

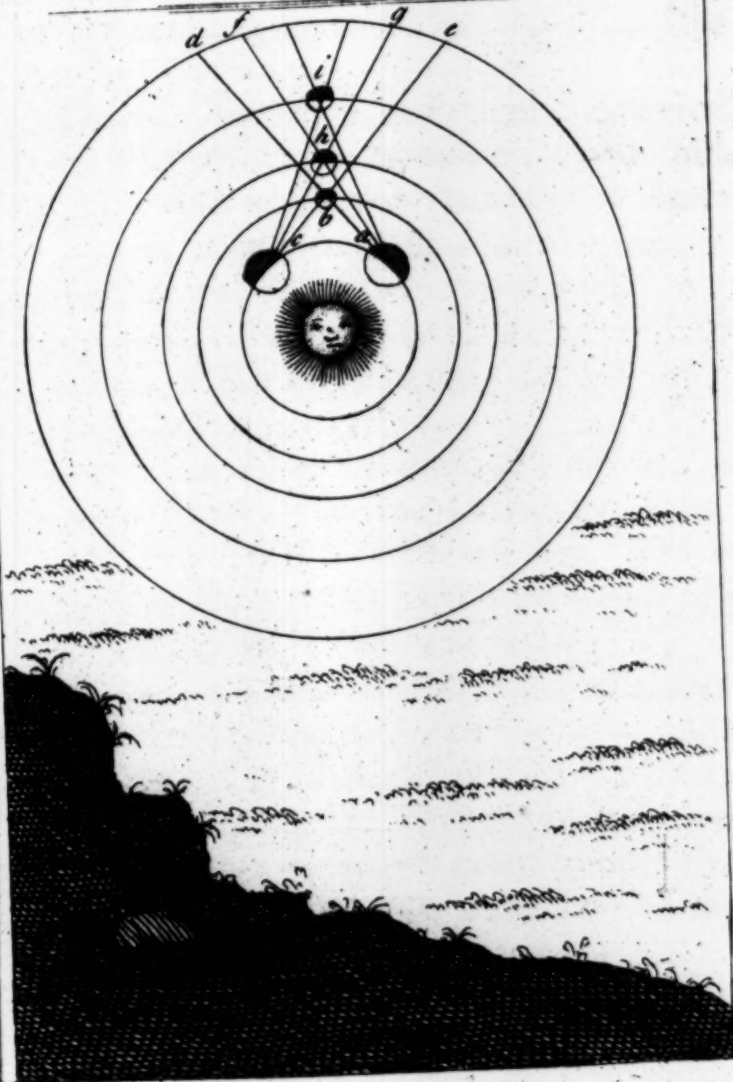
Eudox. They ought therefore to be also more frequent in *Venus* than in *Mercury*; since *Venus* takes more time to run through her Orbit than *Mercury*.

Arist. This excess of Velocity in *Mercury* cannot bring him oftner back toward the West than *Venus*, unless he appear oftner *Retrograde*. Now this excess of Velocity does bring him oftner again toward the West in the inferiour part of his Circle. Therefore, &c.

Eudox. But why does *Mars* being *Retrograde*, describe a greater Arc, than *Jupiter*; and *Jupiter* a greater, than *Saturn*?

Arist. The visual Ray (*a*) Fig. 26. which goes toward a direct Planet (*b*) and the Ray (*c*), which goes toward a *Retrograde* Planet (*b*), cut one another in the Center of the Planet; and after they have cross'd one another, they terminate in different parts (*d*, *e*) of the Heaven. The Arc (*d*, *e*) contained between the two diverging Rays, is the Arc of *Retrogradation*. This being granted; the Arc of *Retrogradation* (*d*, *e*) is so much the larger, the nearer the Earth the Rays cut one another in the Center of the Planet (*b*); and so much the

fig. 26.



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the less (*fg*), the farther distant from the Earth the Center of the Planet (*h*) is; since Angles formed by visual Rays diminish proportionally as the Objects remove *. Now, *Mars* (*b*) is nearer the Earth than *Jupiter* (*h*), and *Jupiter* (*h*) is nearer than *Saturn* (*i*). Therefore the Arc described by *Mars* when *retrograde*, ought to be greater than that of *Jupiter*, &c.

Eudox. But *Mars* in Perigeon is nearer the Earth than *Mars* in Apogee, notwithstanding the Arc of *Retrogradation* in *Mars* in Perigeon, is less than in *Mars* in Apogee, according to the Observations of *Kepler*. Why does this excess of Proximity diminish his Arc of Retrogradation, instead of augmenting it?

Arist. If *Mars* in Perigeon had the same relative Velocity as the Earth, or if in the same time he described an Arc, which answered to that of the Earth, he would not appear *retrograde*, notwithstanding his excess of Proximity. Consequently if the excess of Velocity of *Mars* in Perigeon, above *Mars* in Apogee, surpasses the excess of the Proximity to the Earth, the Arc of *Retrogradation* ought to be smaller in *Mars* in Perigeon, than in *Mars* in Apogee. But, according to the Observations of *Kepler*, the excess of Velocity in *Mars* in Perigeon, surpasses his excess of Proximity to the Earth, either because he is in

* 20 Convers. Vol. II.

the smallest part of his Orbit, or because he is at the same time nearer the Sun, and the Center of his Motion.

Eudox. What you say is ingenious; but it supposes the immobility of the fixed Stars, and yet they move upon the Poles of the Ecliptick, always parallel to the Ecliptick, from West to East. For the first Star of *Aries*, which was 330 Years before *J. C.* at the Interfection of the Ecliptick and Equator, was advanc'd six Degrees 40' in the time of *Ptolemy*^b. It is at present at 29 Degrees toward the East, still placed above the Ecliptick, and it makes about one Degree in 70 Years^c: so that the Sun returns to the Interfection of the Ecliptick and Equator, or to the Point of the Equinox, almost a Month before he overtakes a Star which was found there about two thousand Years ago; and this is what they call the *Anticipation* or *Precession* of *Equinoxes*. Consequently the fixt Stars are not properly fixt; and they make an intire Revolution in 25200 Years^d, or thereabouts^e. In short, the same fixt ones continually remove from, or approach to the Pole of the Equator. The Polar Star, which in the time of *Eudoxus* was twelve Degrees distant

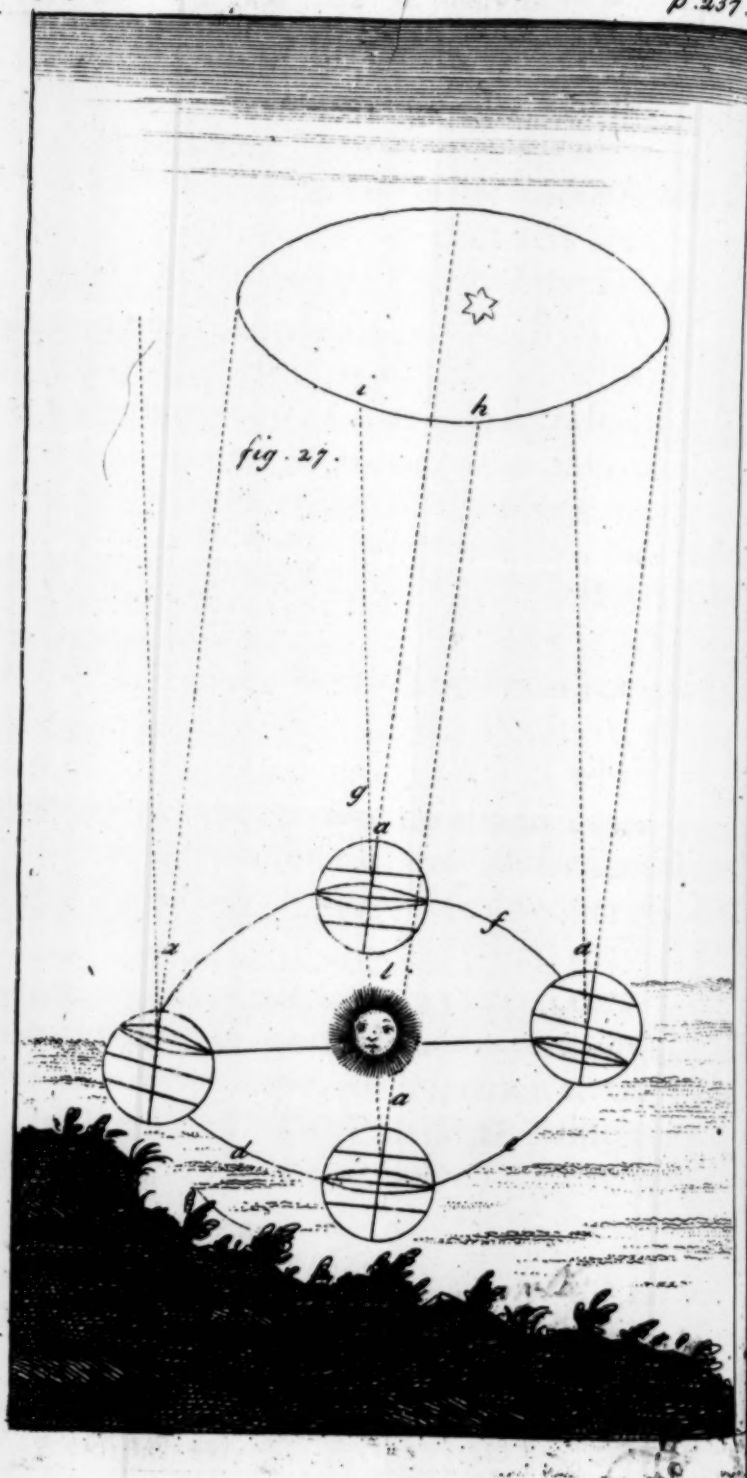
^b Hist. de l'Acad. 1708. p. 96.

^c Tycho, Gassendi, Riccioli Almag. l. 6. c. 16. Hist. del'Acad. 1708. p. 94, 96. Cassini Hist. de l'Acad. 1708. p. 94.

^d According to Cassini, Hist. de l'Acad. 1708. p. 94.

^e According to Tycho, in 25806; according to Gassendi, in 25000; according to Riccioli, in 25920. Almag. T. 1. l. 6. c. 16. p. 445, 446, 447.

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from the Pole of the Equator^f, is now not farther distant than two Degrees 18 Minutes^g.

Arist. If we may suppose that the Motion of the Stars upon the Ecliptick, or parallel to the Ecliptick, is only in Appearance, the Objection is vain; but we may suppose it. For, the Axis (*a*), Fig. 27. of the Diurnal Motion, or of the Equator of the Earth, being always 23 Degrees and an half inclined upon the Plane of the Ecliptick (*cdef*), the Axis of the Equator (*a*), and the Axis of the Ecliptick (*g*), cut one another after such a manner as to determine these fixt Stars in the Heaven; the one, the Pole of the Terrestrial Equator (*b*), and the other the Pole of the Ecliptick (*i*), making together an Angle (*bil*) of twenty three Degrees and an half. Suppose the Pole of the Equator turns round the Pole of the Ecliptick from East to West, so that it always makes with it an Angle of twenty three Degrees and an half; the Equator of the Earth will always change with respect to the Heavens, and will pass thro' other fixed Stars, while the Ecliptick of the Earth, whose Axis is immoveable, will make no change in the Heaven. The Equator of the Earth will cut the Ecliptick in Points more Westward; and consequently the fixt Stars, which will always be in the same Points of the immoveable Ecliptick, will appear to

^f Ric. Almag. Nov. T. 1. l. 6. c. 4. p. 404, 405.

^g Hist. de l'Acad. 1708. p. 94.

remove from the Intersection, and to advance from West to East one Degree in seventy Years, and to accomplish their Circle in 25200, or thereabouts.

Eudox. But the Axis of the Terrestrial Equator cannot move after this manner, without ceasing to be parallel to it self in its different Situations.

Arist. That is true; but a defect of Parallelism, which is only fifty one Seconds distributed into a whole Year, is imperceptible. Now the defect of Parallelism, in the Hypothesis which we are now speaking of, is only fifty one Seconds, by reason of the extreme slowness of the circular Motion of the Axis of the terrestrial Equator round its Ecliptick *.

Eudox. As for the Perigeon and Apogeon of *Mars*, *Jupiter*, and *Saturn*, and the difference of their apparent Bigness in their different Situations, we comprehend them immediately.

Arist. As the Earth is very far distant from the Sun, which is in the Center of the Vortex, the Perigeon of *Mars*, *Jupiter*, and *Saturn*, happens when they are in Opposition, or when the Earth is between them and the Sun. Their Apogeon happens, when they are in Conjunction, or when the Sun happens to be between them

* Hist. de l'Acad. 1708. p. 96.

and the Earth. They appear bigger in their Perigeon, and smaller in their Apogeeon; because Objects increase or diminish in size, in proportion to their distances^h.

Eudox. It must be allowed Astronomy is sufficiently to be accounted for by the Hypothesis of *Copernicus*: but we shall see what Method you will take to reconcile it with Philosophy.

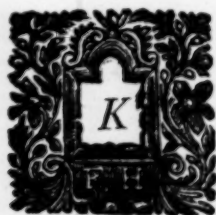
^h 20 Convers. Vol. II.



CON-



CONVERSATION XVI.

*Upon the System of COPERNICUS.**Eudox.*

EPLER's Rule, so famous among the Astronomers, and which seems to favour the Hypothesis of *Copernicus*, does it not also seem to overthrow it?

Arist. Pray, *Eudoxus*, begin with giving me some Idea of this Rule*.

Eudox. They call a *Square* Number the Product of a Number multiplied by it self; a *Cube* the Product of a Square multiplied by the first Number; the *Square Root*, a Number whose Multiplication gives the Square; the *Cube Root*, a Number, whose Square multiplied by the said Number gives the Cube. For example, four is the Square of two; eight the Cube of two; two the Square Root of four, and the Cube Root of eight.

* See Notes to Conversat. 21. *infra*.

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This being granted; What is *Kepler's* Rule? It is a Rule, which expresses the Proportion that is between the Distances of the Planets from the Sun and their Revolutions; and here it is: "The distances of Planets from the Sun are to one another, as the Cube Roots of the Squares of their Revolutions" ^a * : Call to mind in the first place the Duration of those Revolutions ^b. The Numbers, which express this Duration, being multiplied, every one by themselves, see what are the Cube Roots of the Products or Squares. These Roots express the difference of the distances.

For Example, 1, 12, 30, express the Duration of the Revolutions of the Earth, *Jupiter* and *Saturn*; since in the Hypothesis of *Copernicus* and *Kepler*, the Earth compleats its Revolution round the Sun in a Year, *Jupiter* in 12, and *Saturn* in 30, or thereabouts. Multiply separately 1 by 1, 12 by 12, and 30 by 30: you have 1 the Product of 1 by 1; 144, the Product of 12 by 12; and 900, the Product of 30 by 30. 1, 144, 900 are the Squares of 1, 12, and 30.

What are now the cubical Roots of these Squares? 1; 5, a little more; and 10, a little less. For 1, the Product of 1 by 1, only gives 1; 5 multiplied by 5 gives 25, and 25

^a Kepl. Epir. Astron. l. 4. p. 455. Hist. del'Acad. 1705. p. 118. Mem. 1716. p. 217, 219.

^b 17 Convers. p. 189. T. 3.

* See Notes to Conversat. 21. *infra*.

multiplied by 5 gives 125, a little less than 144; 10 multiplied by 10 gives 100, and 100 multiplied by 10 gives 1000, and consequently 900, a little more. Therefore the cubical Roots of 1, 12, 30 are about 1, 5, 10.

Hence, 1, 5, 10, or thereabouts, express the Distances of the Earth, *Jupiter* and *Saturn* from the Sun. These Distances are as 1, 5, 10, or thereabouts. The Distance of *Saturn* from the *Sun* is about 10 times as great as that of the Earth; the distance of *Jupiter*, 5 times; the distance of *Mars*, at least one time and an half; the distance of *Venus*, about 3 fourths of that of the Earth; the Distance of *Mercury* a third^c. Is the Distance of the Earth from the Sun 33 Millions of Leagues^d? That of *Saturn* will be ten times 33 Millions of Leagues, a little less, or about 300 Millions of Leagues; that of *Jupiter*, 5 times 33 Millions of Leagues, or 165 Millions of Leagues, &c.

Arist. I think I understand the famous Rule.

Eudox. They pretend that this Rule is confirmed by eleven Planets, whose distances, in regard of a common Center, and Revolutions round about this Center, are known immediately even by Observation. These eleven Planets are *Mercury* and *Venus*, the

^c Kepl. Epit. Astron. p. 455.

^d 14 Convers. Vol. 3.

four Satellites of *Jupiter*, and five of *Saturn*.*

Arist. You seem, *Eudoxus*, to make use of *Kepler's* Rule in a Design of combating the System of *Copernicus*; but does it not confirm the same? It cannot overturn the System of *Tycho*, without confirming that of *Copernicus*: now it overturns, or at least seems to overturn that of *Tycho*. The Rule is false, or the System is false: it is false, I say, or the System is false, if in this System it ascribes to the Sun and Moon a proportion of Distance from the Earth incomparably less than it really is; but it gives such a Proportion. For according to *Tycho*, the Moon and Sun turn round the Earth, the Moon in one Month, and the Sun in twelve. The cubical Roots of the Squares of 1 and 12 being 1, and a little more than 5, the distances of the Moon and Sun from the Earth ought to be, according to *Kepler's* Rule, as 1 and 5, or thereabouts; wherefore the Sun would only be about five times farther distant from the Earth than the Moon: but this Proportion of distance is incomparably less than the real Proportion; since the Moon has one degree of Parallax, and the Sun has at most 10, according to the most skillful Astronomers. Therefore *Kepler's* Rule, if one suppose it true, confirms the System of *Copernicus*.

* Hist. del'Acad. 1705. p. 118, 119.

Eudox. And for my part, I say, that supposing it true, and that the Circles of the Planets have the Sun for their common Center, as in the Hypothesis of *Copernicus*, the Laws of Physicks are thereby destroyed. For according to this Rule, the real Velocities of Planets will always be greater, proportionally as the Planets shall be nearer the Center or the Sun. These Velocities will answer to the Roots of the reciprocal Distances. The real Velocities of the Planets will diminish proportionally as the Planets shall be farther distant. Their Velocities will be about the half less than their distances. For example, a Planet four times farther distant from the Sun than another, will have two times less Velocity.

Arist. The Planets effectually diminish in real Velocity, in proportion as they are distant from the Sun^f. *Mercury* makes his Revolution round the Sun in almost 3 Months, and is about three times nearer the Sun than the Earth; consequently the Earth ought to compleat its Revolution round the Sun in 9 Months, in order to equal the Velocity of *Mercury*. It only compleats it in 12, therefore it has less real Velocity. The same is the Case with *Venus*. And the same thing is observed in the subaltern Planets, that is in the four Satellites of *Jupiter* and five of *Saturn*, whose Distances from a common Center we immediately perceive. We see the same Planet augment

^f M. Cassini, du Progrès de l'Ast. p. 36.

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in Velocity in proportion as it approaches to its Perihelion, or on the contrary. Does the Sun approach his Perigeon ? We see his Velocity augment more than his Diameter ; and consequently the Augmentation of Velocity is not a simple Appearance caused by a greater Proximity. Therefore there must be something real in it ; and if the Earth move, it really moves more swiftly, when it is nearer the Sun. Therefore the Planets have so much the more Velocity, the less distant they are from this Luminary.

Eudox. This being granted ; a System, in which the inferiour Planets ought to come out of their Spheres, pass off toward the Extremities of the Vortex, and make the superiour Planets to descend into their Place, is a System which has no foundation : But this is what ought to happen in the Hypothesis of *Copernicus*. The inferiour Planets having more Velocity, have a greater central or centrifugal Force, in order to pass off toward the Extremities of the Vortex.

Arist. The excess of Velocity, which is in the inferiour Planets, does not give them a greater central Force than that of the superiour Planets, if the superiour Planets have an excess of Mass or Solidity, greater than this excess of Velocity ; since the Motion, and consequently the centrifugal Force, is equally measured both by the Mass, Solidity, and Velocity,

locity ^e, and a Body larger or more solid, has less Surface in regard of its Mass ^h, has its Force less distributed, and unites the more of it for the producing of the same effect. Now the superiour Planets may have an excess of Mass or Solidity, greater than the excess of Velocity, which is in the inferiour Planets.

Eudox. But the Earth is almost of the same bulk as *Venus*, and that of *Mars* is at least seven or eight times less than that of the Earth, or of *Venus*. How then can the Earth have more Mass or Solidity, more central Force than *Venus*; and *Mars*, more than the Earth?

Arist. Neither the equality nor excess of Bulk makes the equality or excess of Solidity or Mass. The Earth may be more massy and solid than *Venus*, tho' it is nearly of the same Diameter. *Mars* it self may be more massy and solid than the Earth, tho' it is much smaller. We may say that *Mars* exceeds *Venus* and the Earth in Solidity, in proportion as its Velocity, or excess of Distance from the Sun, affords it less centrifugal Force. We may say as much of every part of the Fluid, which composes the spherical Surface in which *Mars* moves.

Eudox. The Sun must be in the Center of the Vortex; the Matter, which occurs toward the Center, must be the finest and most agitated Matter of the Vortex; and it must always

^e 7 Convers. Vol. 1.

^h 8 Convers. Vol. 1.

become more and more dense toward the Extremities. But how can that be? A Volume of this more subtile and agitated Matter, would have more centrifugal Force, than an equal Volume of globulous Matter, and which one supposed more condensed, since it would have more Velocity, and as much Mass in effect; for there is no vacuity.

Arist. Two equal Volumes, the one of finer Matter, and the other of Matter more compact and solid, have an equal number of determinate parts. Nevertheless that whose Matter is more solid, may have more central Force, even with less Velocity; because its Force being less distributed, less dissipated, or more united, contributes more to produce the same effect. Divide a small Ball into a great quantity of Particles: these Particles have all together less efficacy to remove from the same Center, than they had formerly when united in the same solid Mass; because formerly all their Forces conspired to the same effect; and after division, they not only direct their Action towards different parts, to the left, to the right, upwards, and downwards; but they have besides more Surface in proportion to their Mass. Therefore the finest and most agitated parts of the Vortex, ought not to have a greater central Force than the others.

Eudox. But, *Aristus*, whence can this excess of Velocity proceed in those Circles of

etherial Matter, in proportion as they approach to the Sun?

Arist. From the Action of the Sun itself upon them, which ought to abate in proportion as it passes into the upper and larger Circles, and is communicated to a great number of parts.

Eudox. I don't at all see upon those principles what can determine the Planets to cut the Ecliptick at different Angles. How can the Orbits of *Mercury* make with the Ecliptick an Angle of six Degrees, the Circle of *Venus* an Angle of three Degrees and an half, that of *Mars* an Angle of 1 Degree 50 Minutes, and that of *Saturn* an Angle of 2 Degrees 50 Minutes¹.

Arist. Different Boats * and different solid Bodies being abandoned to the Current of a River, receive from it Directions which cut the middle of the River at various Angles, according as the Bodies present to the Current different Figures, more or less unequal Parts, different Situations, or as Brooks or Torrents enter into the River with divers Directions. May not one say as much of the Planets carried in the etherial Matter?

Eudox. But if the Equator of the Sun, or the great Circle which it describes in revolving upon its own Axis, makes with the Ecliptick

¹ M. Villemot. p. 150.

* See Notes to Convers. 15. *supra*, and 21. *infra*.

an Angle of seven Degrees and an half, or thereabouts, as some skilful Astronomers have observed ^k, the Planets carried in the Sun's Vortex, ought I think to describe Orbits parallel to the Sun's Equator, and all of them to make with the Ecliptick the same Angle.

Arist. The difference of Figure in different Planets, the difference of Solidity in the parts of the same Planet, and different Situations in regard of the Current of ethereal Matter, may determine it to give them Directions, which are not parallel to the Sun's Equator, but which carry the Earth through the Ecliptick, and make the Ecliptick to be cut by the other Planets; as the difference of Figure, Solidity, and Situation in divers Boats, determine the Current of the River to give them different Directions, some parallel to the Axis of the River, and others variously inclined to this Axis.

Eudox. Do you believe then, *Aristus*, that a Body as big as the Earth can naturally turn round the Sun?

Arist. *Jupiter* and *Saturn*, 1000 times bigger than the Earth, incessantly turn round the Sun; why may not the Earth turn round after the same manner?

Eudox. Those who are under the Equator would make 9000 Leagues every day, with-

^k *Father* Scheiner. J. M. Cassini, Découv. de la Lum. cél, &c. p. 17. Rec. d'Observ. par les Mess. de l'Acad.

out being sensible of it, by turning round upon the Axis of the Earth.

Arist. We make 100 Leagues in 24 hours aboard a Vessel, without being sensible of it; why might we not insensibly make 9000 Leagues with the Earth? As the Atmosphere would turn round as swiftly as the Earth, this Revolution would not cause any change in the Eyes, and would be perfectly imperceptible.

Eudox. Turning one's self round about for some few Moments, dazzles one; and would not turning round 9000 Leagues in twenty four hours cause any dazzling?

Arist. When one turns one's self rapidly about, new Objects strike the Eyes every moment; the successive, quick and repeated action of those Objects upon the Senses, causes therein some changes, dazzlings. The Direction which the Animal Spirits have acquired, subsists for some time after one has ceased to turn round; and hence every thing seems still to turn round about you. But one may make 9000 Leagues with the Earth, without ceasing to see the same Objects, and without any change, any alteration being made in the Senses.

Eudox. At least the Western Mountains would appear to be elevated, or to ascend every instant.

Arist. To ascend with respect to us, is to approach our Zenith. Now the Western Mountains would not approach our Zenith, since

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since it would advance toward the East proportionally as we our selves advanc'd toward the same part ; the Zenith is moveable. It is always the most elevated Point, which is directly over our heads. And this seems to me sufficient for shewing that the Hypothesis of *Copernicus* may be supported as an Hypothesis ; at least it is what they say in favour of this Hypothesis.

Eudox. It is ingenious. It explains the Phænomena of Nature, at least the most part of them. Nevertheless, notwithstanding the bias I see you have towards it, I believe you will adhere to the Hypothesis of *Tycho* a little changed, as well as I, in our next Conversation.



CON-



CONVERSATION XVII.

*Upon the System of TYCHO.**Arist.*

CONFESS, *Eudoxus*, the great Circle, which they make the Earth describe in the System of *Copernicus*, frightens you. You are afraid to expose your self to the making so much way in so little time.

Eudox. The enormous way which one makes in so short a time in this Hypothesis, does not at all alarm me; and besides, I should make it as speedily as you. But a System which appears more conformable to the Scripture *, and which at the same time is reconciled

* As the *Copernican* System is demonstrably true, all the Remarks we shall subjoin to this Conversation, is what follows from the learned Dr. *John Clarke*. It is evident, says he, from a cursory View of the Old and New Testament, that they are Miscellaneous Books, containing great variety of Things, and taking in a large compass of Time; some parts of which are History, others writ in a Poetical Style, and others Prophetical: But the Design of them all is professedly to recommend the Practice of true Religion and Virtue. It is with this View therefore that we are to understand any Expression contained in them. This Method we naturally take with respect to all other Books.

ciled with the principal Phenomena of Nature, ought to please me better. Now, 1. The System

Books. No one reads a Treatise of Philosophy, but he expects to find that the Terms mentioned there, be used in a Philosophical Sense; and accordingly he always apprehends them so. But if in such a Treatise there should *incidentally* be brought in something upon a different Subject, and described according to the *Vulgar* way of speaking, without any regard to *philosophical* Truth; he would not pretend to explain such an occasional Discourse in the same manner as he did the rest of the Book. And the like holds true with regard to the Scriptures. They are not Books of Metaphysics and Philosophy, design'd to entertain Men's Curiosity with nice Speculations; but they are Books of Religion and Morality, calculated for the regulation of Mens Behaviour and Practice. And because no Language abounds with Words sufficient to express the Particulars of all Sciences, therefore some of them must necessarily be used in different Senses as they relate to different Subjects. The common People, in those things they are conversant about, and have occasion to take notice of, express things as they appear to the Senses, and not as what in strictness and reality they are; which is sufficient for the purposes of Life. But whoever would enquire into the Truth of such Things, and examine the Foundation of such Appearances, must express himself very differently, therefore there must be both a *vulgar* and *philosophical* way of expressing the same thing; which whoever confounds or misapplies, immediately introduces innumerable Absurdities. These Distinctions have place in the forementioned Books; and the not attending to these Distinctions, has rendered many things there utterly unintelligible, and others contrary to Fact and Experience. For want of attending hereto, some Persons have laboured under inextricable Difficulties how to reconcile some of the most certain Truths in the natural System of the World, such as the Motion of the Earth and the like, with the Representation made of them in Scripture: Whereas upon this single Supposition, that the Scripture is a Book of *Morality*, and not of *Philosophy*, it ought to be very exact in conforming all its Words and Expressions to the *moral* or *religious* Sense of them; but the other being foreign to this Subject, and only occasionally introduced, there is no need of such accuracy in them, but they *may* safely, nay it would be absurd if they should *not*, be delivered according to the vulgar acceptation of Words, as not being at all intended to inform Men in those Matters. Every Difficulty upon this account immediately vanishes. *Boyle's Lectures*, vol. 2. p. 57, &c.

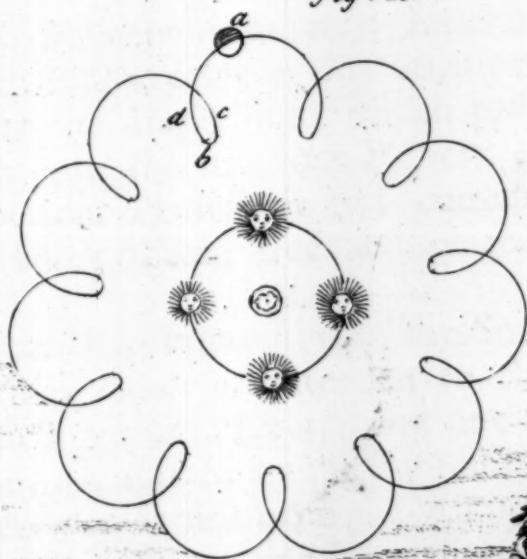
System of *Tycho*, which fixes the Earth, and makes all the Luminaries to revolve round it, seems more conformable to Scripture. "God," says the Scripture *, has fix'd the vast Body "of the Earth, so that it shall not be shaken. "The Sun rises and sets; and returns to the "Place whence he came, in the same Place "he rises again. He takes his Course toward "the South, and turns toward the North †."

2. In this System we see the Causes of the principal Phenomena. The diurnal Motion of the Sun, from East to West, makes the Days; his Revolution from West to East, according to the Order of the Signs of the *Zodiac*, makes the Years: his successive Positions in *Aries*, *Cancer*, *Libra*, and *Capricorn*, make the different Seasons; the Excentricity of the Circles of the Planets makes their Apogee and Perigee; the spiral Lines of the superiour Planets, and the Revolutions of the inferiour round the Sun, make the Directions, Stations, and Retrogradations. The Planets situated in the upper part (*a*) of their Epicycles are direct, since then one sees them advance from West to East, Fig. 28. In the inferiour part (*b*), they are retrograde; then they come from the East toward the West. While they ascend (*c*) or descend (*d*), you say that they are stationary; because being then in a part of their Circle, almost parallel

* Ps. 92. ver. 2.

† Ecclesiast. chap. 1. ver. 5.

fig. 28.



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to the visual Ray, their Motion is imperceptible.

The Directions, Stations, and Retrogradations of the inferiour Planets, and a great number of other Phenomena, are explained as in the System of *Copernicus*. Therefore I chuse to hold by the System of *Tycho*, especially if they change some Circumstances. In this Hypothesis, the Sun carries along both the inferiour and superiour Planets, while the Earth remains immoveable between those Planets.

Arist. Philosophy suffers a little in seeing the Earth immoveable in this Situation. How is it that the Impression, which passes from the Sun into the inferiour Planets, as far as the superiour Planets, is not communicated to the Earth, being free and placed in the middle?

Eudox. The Impression of the Sun's Revolution may either be extended to the Earth, or to the superiour Planets; and one may say, that they are moved by the Impression, which they received at first from the Author of Nature, who preserves this Impression.

Arist. But can it be that a Liquid, which contains the Moon, Sun and Planets, should turn round the Earth, without the Earth's turning round?

Eudox. Oftentimes the superiour part of the Atmosphere runs from West to East, without its Action descending to the Earth; since
we

we often see Clouds strongly elevated advance rapidly toward the East, while we see the inferiour Clouds very quiet. Therefore it is not necessary, that the turning round of a Liquid infinitely distant from us, should be communicated so far as to the Earth.

Arist. At least, the Luminaries would have two opposite Motions at a time, the one from East to West, and the other from West to East.

Eudox. 1. The one is a common Motion, the other proper; and two Motions of this kind are not incompatible. One walks from the East toward the West, upon a Vessel carried from the West toward the East. 2. Those two Motions of the Luminaries are not directly opposite; since they cut one another, making an Angle of 23 Degrees and an half. But I see, *Aristus*, I may say what I will, the Simplicity of *Copernicus*, and a certain Air of Novelty, affect you. For my part, I will say of the Sun, as *David* did, "He comes forth full of ardour to run his race like a Giant. He proceeds from one end of the Heaven, and arrives at the other*."

Arist. I will glory in thinking and speaking as you do.

Eudox. Finally, *Aristus*, the Eclipses of the Luminaries, and the Comets, would also deserve some particular Conversations, as I think.

* Pl. 18. 7.

Arist.

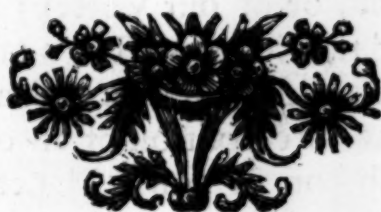
Arist. I shall willingly explain myself upon the Eclipses, and gladly hear you upon what concerns Comets.

— *Dulces ante omnia Musæ.*

— — — — — *monstrent*

Defectus solis varios, Lunæque labores.*

* Virg. l. 2. Georg. v. 475, 477, 478.





CONVERSATION XVIII.

*Upon Eclipses of the SUN.**Arist.*

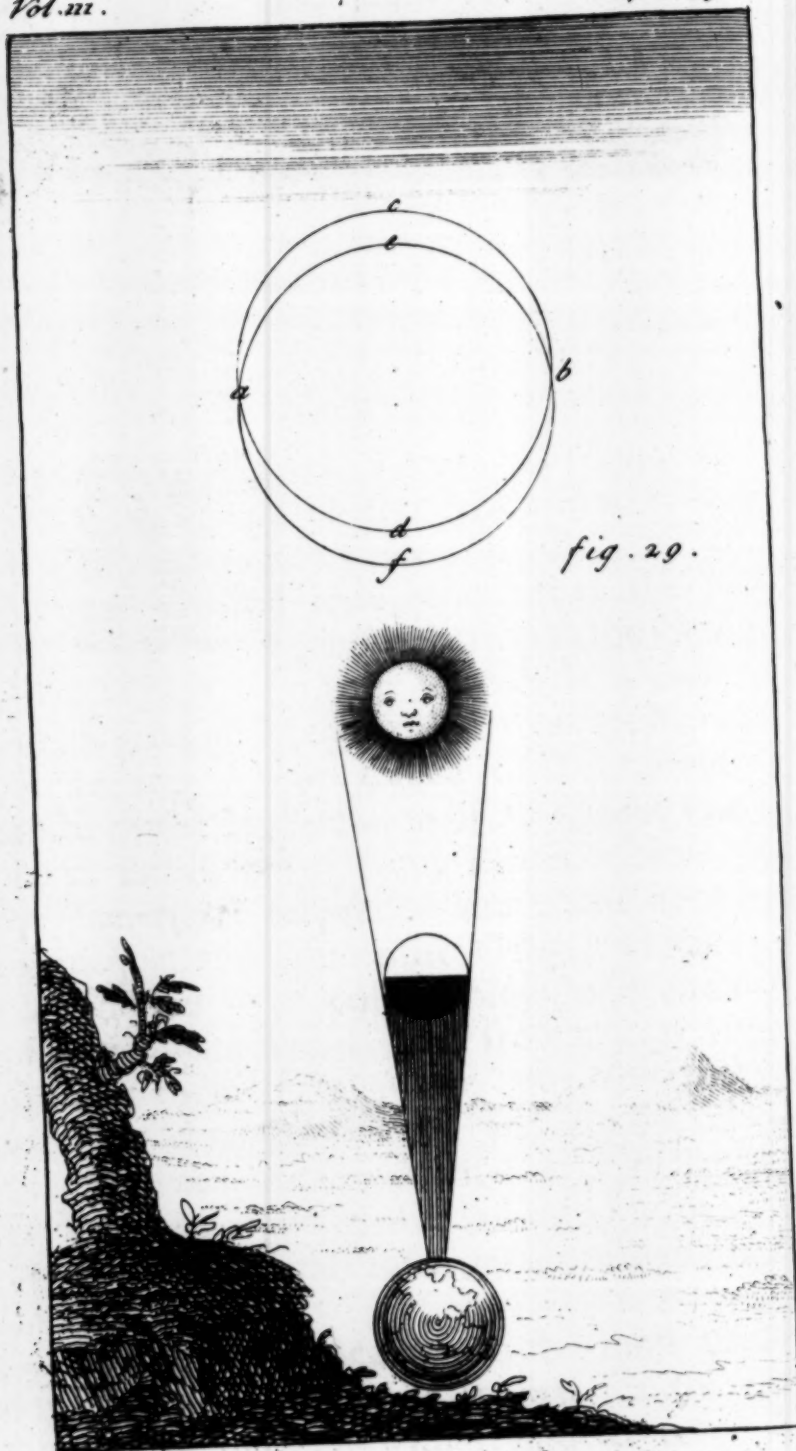
WHEN one has some Idea of the Arrangement, and relative Situation of the Luminaries, that the Sun or the Earth is in the Center of the World, or of our Vortex; it is easy to comprehend the Eclipses. They call an Eclipse, the fleeting Disappearance of a Luminary, caused by the Interposition of an opaque Body, of the Earth, or of some Planet. Now, as the Planets are suspended above one another in unequal and concentric Orbits, which cut one another in opposite Points, and enclose the Earth, it is natural, that from time to time some of them meet in the same visual Rays with superiour Luminaries, and deprive us of the Light of those Luminaries by their Density. Hence, the Eclipses of the Sun, Moon, Planets, both superiour and inferiour, the Satellites, and the Stars.

Eudox. Let us begin with the most affecting Eclipses. What is it that causes the Eclipses of the Sun with regard to us?

Arist.

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Arist. The Interposition of the Moon, which incessantly revolves round the Earth, as a Satelles of the Earth, and passes between the Sun and us. Is the Moon directly between us and the Sun? She hides this Luminary from our Eyes; or, which is the same thing, she casts her Shadow over us: and this is an Eclipse of the Sun, with respect to us. Accordingly the Eclipses of the Sun happen only in the Conjunctions, or at the New Moons; that is, when the Moon is interposed between the Earth and the Sun; and the Eclipse answers to the Situation of the Moon, with respect to the Sun, and our Eyes.

Eudox. But why do not Eclipses of the Sun happen in all New Moons? We seldom observe above two or three in a Year.

Arist. The Orbit (*a c b d*) of the Moon, cuts the Ecliptick (*a e b f*) in two opposite Points (*a, b*) Fig. 28. making with this Circle Angles of about five Degrees *. They call those Points or Sections, Nodes, or the Head and Tail of the Dragon. The one (*a*) of the Nodes they call the ascending Node, or the Head of the Dragon. The other (*b*), the descending Node, or the Tail of the Dragon. The first is the Section thro' which the Moon passes from the South towards the North; and the second is the Section thro' which the Moon passes from the North toward the South; two changing Sections, which move

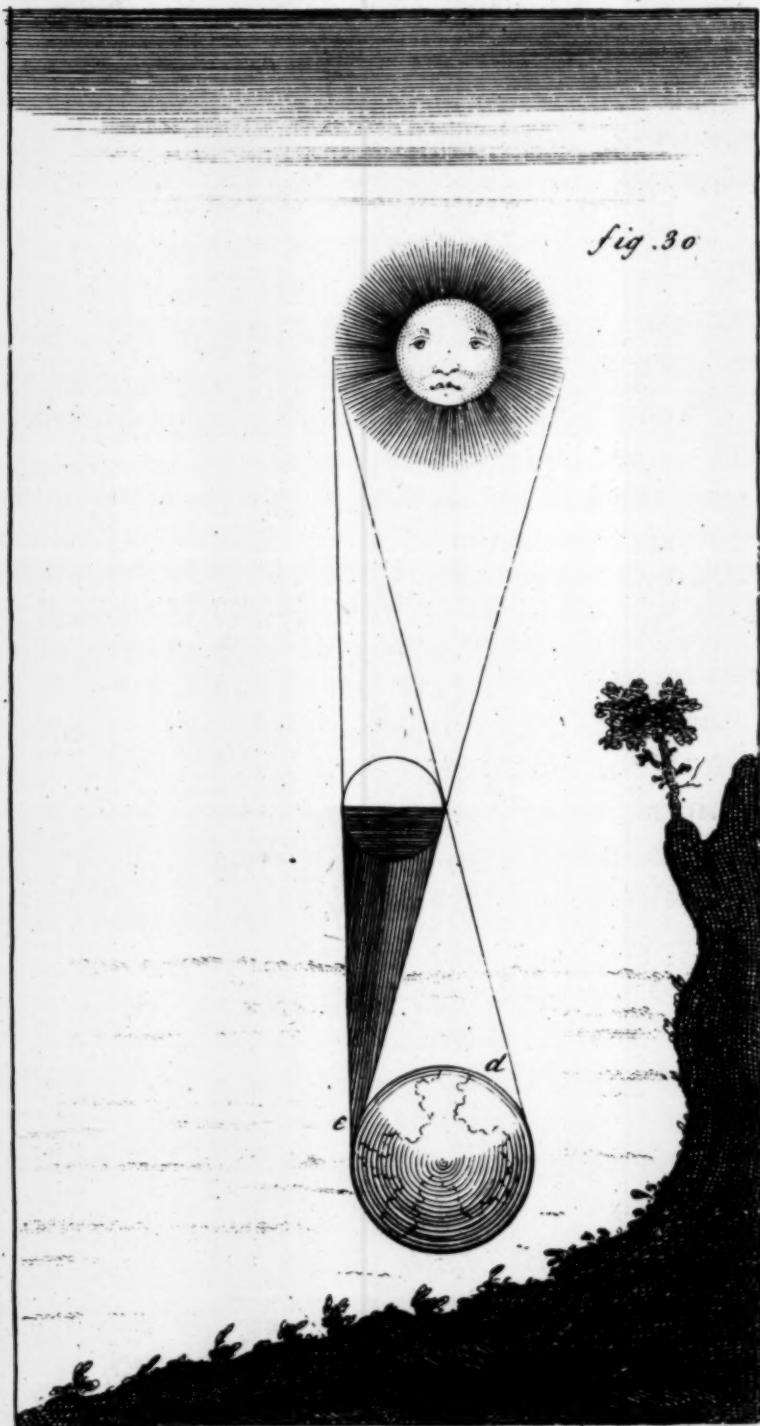
* 11 *Convers. supra.*

from East to West, and make a Revolution in 19 Years, or thereabouts.

This being granted ; no Eclipse of the Sun ought to happen, with respect to us, but when the Moon is between us and the Sun. *Mercury* and *Venus*, which are the only Planets beside the Moon, that can pass between the Sun and us, can only hide a part of him from us, which is imperceptible, or almost so to the naked Eye. Now the Moon can scarcely occur between us and the Sun more than two or three times in a Year. For she cannot be in such a Position, but when she is with the Sun, and under the Sun, in one of the Nodes, or very near. In every other Situation she has too much Latitude, is too far distant from the Ecliptick, and consequently from the Sun, which never comes out of it, to be between this Luminary and our Eyes ; and the Moon is only with the Sun in the Nodes twice every Year, since the Sun, which employs a Year in running over the Ecliptick, during all this time is only once in the Point (*a*) of this Circle, and once in the Point opposite (*b*). The Moon cuts the Ecliptick twice every Month ; for it makes a Revolution in the *Zodiack* in a Month ; but the Sun occurs only once in a Year in each of the Sections, or twice in the Nodes. Therefore instead of seeing Eclipses of the Sun at every New Moon, they ought scarcely to happen twice or thrice a Year.

Eudox.

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Eudox. At least the Sun ought, I think, to be eclipsed every six Months with respect to us, since every six Months, or thereabouts, he passes thro' one of the Points or Nodes in which the Moon cuts the Ecliptick, and in which consequently the Moon ought to be between the Sun and us.

Arist. The Sun ought not to be eclipsed with respect to us, but when our Eye, the Moon and Sun are in the same Line, in the same visual Ray. Now our Eye, the Moon and Sun do not occur every six Months in the same Line, in the same visual Ray. Sometimes the Sun reaches the Node sooner than the Moon, or the Moon sooner than the Sun; and as the Nodes are changeable, the Sun and Moon, even when they encounter one another therein, are not always in the same Situation with respect to us; the Sun is hid in them from other Countrys (*c*), without being with-held from our Eyes (*d*), Fig. 29. Therefore we ought not to see Eclipses of the Sun every six Months.

Eudox. Do you see, *Aristus*, upon the same Principles, the beginning and end of solar Eclipses?

Arist. Solar Eclipses begin at the western Limb of the Sun, at least ordinarily, and end at the eastern. Because the Moon going more swiftly than the Sun, from the West toward the East, since she compleats her Revolution in less than a Month, her oriental Limb begins

with joining and hiding from us the Sun's occidental Limb, and only leaves him at the oriental Limb, so as to restore him entire to our view.

Eudox. But the Business is to explain, on the same Principles, the Differences of the solar Eclipses.

Arist. Some are partial, others total; some central, others annular^a. An Eclipse is partial, when the eclipsed Luminary does not wholly disappear, or when it preserves a part of its Light, with respect to those who see the Eclipse. It is total, when it wholly disappears, or when the apparent Disk is wholly covered with Shadow. The Eclipse is central, when the Center of the eclipsed Luminary, the Center of the Body which eclipses, the Axis of the Shadow, and the Eye of the Observator, are found in the same right Line. Lastly, the Eclipse is annular^b, when the Circumference of the eclipsed Luminary remains uncovered, and makes a luminous Circle shine round the Body which hides it, as has been often observed.

In order to comprehend these Differences, I observe, in the first place, that according to the Principles of Opticks^c, the apparent bigness of the Disk of the Moon and Sun answers

^a Ric. Almag. T. 1. l. 5. c. 16. p. 231.

^b Cleomedes, l. 2. Cyclicæ Theoriæ, c. 4. Clavius 1567. c. 4. in Sphæratm. Jessenius 1598. Lansbergius 1601. Le P. Taquet. Astron. l. 8. Tract. 3. n. 3.

^c 20 Convers. Vol. 2.

swers to their Distances from the Earth; that it is greater toward their Perigeon than their Apogee; that the apparent Disk of the Moon is sometimes less, sometimes bigger than that of the Sun^d; and that the bigness of the solar Eclipse depends upon the apparent bigness both of the Moon and Sun. In a word, 1. If the Moon, which ought to cause an Eclipse, were so little, or so far distant from us, that she could not be discerned, she would cause no Eclipse. *Mercury* may pass as he pleases below the Sun, he does not in the least eclipse him to the naked Eye. 2. Whenever one of the Extremities of the apparent Diameter of the Sun, is join'd by one Extremity of the apparent Diameter of the Moon, which passes under the Sun from West to East, the Eclipse begins, as we have said; and it ends exactly when the two Diameters are disengaged from one another.

This being granted; 1. If the apparent Disk of the Moon, which happens to be under the Sun, is less than the apparent Disk of the Sun, it does not hide it wholly from our Eyes; and the Eclipse is partial. 2. But are the apparent Diameters or Disks of the Moon and Sun, perfectly equal with respect to us, so that the whole Diameter of the Moon is between us and the Sun? The Eclipse is total, and for one instant only; since in that case the Diameter of the Moon, which ad-

^d Hist. de l'Acad. 1706. p. 115.

vances continually swifter than the Sun from West to East, entirely hides the Diameter of this Planet, but for a single instant. 3. If the apparent Disk of the Moon is greater than that of the Sun, the Eclipse is more than total, if I may so say; and the Sun remains some Moments wholly conceal'd. Some Moments are required, that the Extremity of the occidental Limb of the Moon may permit us to see the occidental Limb of the Sun, in advancing toward the East. 4. If the apparent Diameter of the Sun is a little larger, and the Excess extends every way, the Eclipse is annular^e. There remains a Circumference in the Sun, which is not covered, and which by its Splendour makes an obscure Border or Disk of the Moon; because the obscure Disk of the Moon is not large enough to hide the Sun's Circumference from the Sight.

Every central Eclipse of the Sun is total or annular. For in that case the apparent Disk of the Sun is larger than that of the Moon, or not; if it is larger, the Eclipse is annular, since it advances equally on all sides. If it is not larger, the Eclipse is total, since it is entirely hid by a Disk either larger, or at least equal. But if the Eclipse is total or annular, it does not thence follow that it is central; neither is it necessary that the Center of the Sun, the Center of the Moon, and the Place of Observation should meet in the same Line.

Without

^e Le P. Riccioli Almag. nov. T. I. p. 199. l. 4. de Lunâ, c. 6.

Without this, the Excess of the apparent Disk of the Moon may cover the whole Sun, and the Excess of the apparent Disk of the Sun may advance on all sides.

Eudox. But in what particular Situation of the Moon and Sun is the Eclipse total or annular?

Arist. If the Sun is in his Apogee, and the Moon in her Perigee, directly between the Sun and the Observer, it is natural that the Eclipse be total, since in that case the apparent Diameter of the Moon is larger, and the apparent Diameter of the Sun less. If the Sun is in his Perigee, and the Moon in her Apogee directly between the Sun and Spectator, the Eclipse ought naturally to be annular, since then the apparent Diameter of the Moon is less, and that of the Sun larger.

Eudox. One quickly conceives the Appearances of a total or annular Eclipse. But in 1706, the 21 *May*^f, and 1724, the 22 *May*^g, they had two solar Eclipses total in divers Parts, and more than total, since they remained total for some time; the second for the space of $2\frac{1}{4}$ Minutes; I myself observ'd it. In those Eclipses there appear'd round the Moon a Garland of pale Light, which still grew weaker and weaker without their being properly annular; the Circumference of the
Sun's

^f Hist. de l'Acad. 1706. p. 117.

^g Ibid. 1714. p. 87.

Sun's Disk was not uncovered, the Splendour of the Garland was much less than that of the smallest part of the Sun. Whence can this luminous Garland proceed?

Arist. In 1683^h, M. *Cassini* discovered a Light which follows the Sun, always extended upon the *Zodiack*, and which only appears when the Sun is below the Horizon, always obscur'd by the Light of the Moon, and without that almost continually by the Twilights, which do not permit it to appear but when they are very short. This Light may be caused by some Matter which issues out of the Poles of the Sun, like the magnetic Vortex from the Poles of the Earth and Loadstone, or out of the whole Globe of the Sun, like Exhalations from the Earth; and, as M. *Cassini* seems to have supposed after eleven Years Observations*, diffused in form of an Atmosphere round the Sun to a certain Distance, proportionally thicker as it is nearer this Luminary, and capable of reflecting its Rays towards us, when they cannot come any longer directly to us. Now, is it not probable enough, that the luminous Garland, which has been observed in total Eclipses, is only a Light reflected by this Species of Atmosphere, with which the Sun is environed?

Eudox. However that be, you will not, I guess, imagine to yourself, that a total Eclipse of the Sun may be universal.

Arist.

^h Découv. de la Lum. Cel. &c. p. 3. Rec. d'Observ.

* Ibid. p. 68.

Arist. That an Eclipse of the Sun might be universal, the Shadow of the Moon must cover the whole Earth. But the Shadow of the Moon does not cover the whole Earth. This Shadow answers to the apparent Diameters of the Moon and Sun; and a Shadow of this sort cannot cover the whole Earth; for the apparent Diameter of the Sun is scarcely larger or smaller than that of the Moon, and the Diameter of the Moon is four times smaller than that of the Earth. Hence the Eclipse, which was total in *England* the 31 *May* 1715, was only of $11 \frac{1}{4}$ Digits at *Paris*¹.

Eudox. During the Eclipse, the Shadow of the Moon is successively spread over different Countries of the Earth, with more rapidity than a Cannon-Bullet in the Air². Would you believe it?

Arist. While the Moon runs through one degree of its Orbit, the Shadow of the Moon passes over a space equal to this degree upon the Earth. Now, in order to run over this space, a Motion is required more rapid than that of a Cannon-Bullet in the Air. For a Velocity of 12 degrees in a Minute, or thereabouts, is required. In short, let us apply one degree of the Moon's Orbit upon the Circumference of the Earth; what proportion has this degree to a degree

¹ Hist. de l'Acad. 1724. p. 87.

² Ibid. 1706. p. 166.

gree of the Earth's Circumference? The Circumferences of two Circles are as two Rays; the greater Length the Rays have, the more they diverge; the more the Rays diverge, the greater are the Arcs of the Circumferences contained between the Rays. The Ray of the Moon's Orbit is about 60 times as much as that of a great Circle of the Earth; since the Semidiameter of the Moon's Orbit, or the Moon's Distance from the Earth is about 60 Semidiameters of the Earth. Therefore the Moon's Orbit is about 60 times as much as the Circumference of the Earth; therefore a Degree of the Moon's Orbit is equal to about 60 Degrees of the Earth's Circumference; therefore it is equivalent to about 1500 Leagues: for a Degree of a great terrestrial Circle is equal to 25 Leagues, and 60 Degrees multiplied by 25 Leagues afford 1500 Leagues. But the Moon runs through one Degree of her Orbit in about two Hours, since she runs through 13 every day. Therefore, her Shadow in two Hours, or in the space of 120 Minutes, runs over about 60 Degrees upon the Earth, and consequently about 1500 Leagues. It has therefore a Velocity of almost 12 Leagues in a Minute; for 120 Minutes multiplied by 12 Leagues, or 120 times 12 Leagues make almost 1500. Now a Cannon-Ball has only a Velocity of about three Leagues in a Minute, as we learn from Experience; therefore the
Motion

Motion of the Moon's Shadow upon the Earth is more rapid than that of a Cannon-Ball in the Air.

Eudox. Lastly, when after a total Eclipse the Sun begins to appear again, the first small Portion of the Sun, which discovers itself, darts out a sudden and very lively Splendour¹, which seems to dissipate the whole Obscurity, as I myself have observed.

Arist. When the Sun discovers himself, the Pupil receives at first so many more Rays, the more it has been enlarged in the Shadow of the Eclipse; since the Pupil, which is contracted in the full Light, is dilated in the Dark, as we have before said, and for Reasons which we have mentioned in the Opticks^m; and the Retina is so much the more sensible of the sudden Rays, the less its Fibres were agitated. Hence probably proceeds the Vivacity of the Light, the moment it begins to appear, after a total Eclipse of the Sun.

Eudox. Let us pass, *Aristus*, to the Eclipses of the Moon. I shall shew the Appearances and Circumstances of them. The Remembrance of the Eclipse which appear'd latelyⁿ, will bring them to mind, and I shall have the pleasure of seeing you unravel the Reasons of them.

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¹ Hist. de l'Acad. 1724. p. 87.

^m 20 Convers. Vol. 2.

ⁿ 13 Fevrier 1729.



CONVERSATION XIX.

*Upon the Eclipses of the Moon.**Eudox*ELL, *Aristus*, what is an Eclipse of the Moon?*Arist.* It is the want of Light, caused upon the Surface of the Moon (*a*)

Fig. 31. by the Interposition of the Earth (*b*) with its Atmosphere between the Moon and the Sun (*c*). As the Sun and Moon have unequal Motions, and the Moon cuts the Ecliptick, in which the Sun always is, in two Points, these two Luminaries sometimes meet together in the Nodes or two opposite Points, while the Earth is in the middle, in a Line drawn from the Sun to the Moon. In that case, the Earth with its Atmosphere interrupts the Sun's Rays, hinders them from enlightening the Moon, as before; and this is an Eclipse of the Moon. In short, these kinds of Eclipses do not happen but at the full Moon, that is, when the Earth is between the Moon and Sun.

Eudox. The Shadow of the Earth is Conic, it is an obscure Cone (*def*) of which the Earth is the Base, and contained between the Rays which come from the Limbs of the Sun,
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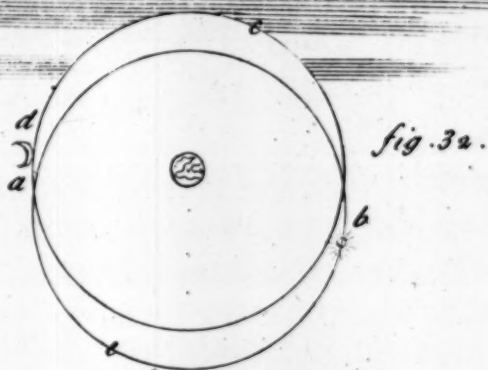
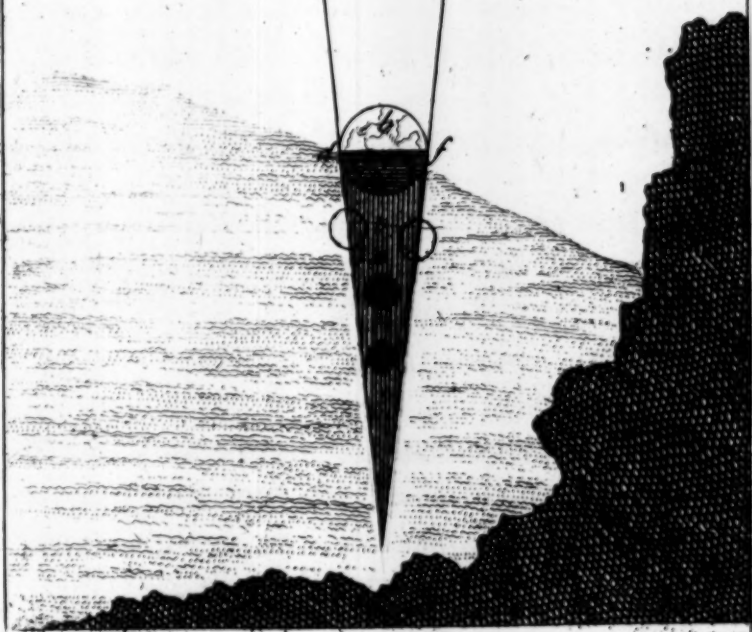


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continually approaching one another, to graze upon the Limbs of the terrestrial Globe, less than the Sun. How does this conical Shadow convey obscurity so far as the Surface of the Moon?

Arist. If the Shadow of the Earth, though conical, extends far beyond the Moon, it is not astonishing that it eclipses the Moon itself. Now the Shadow of the Earth, extends far beyond the Moon. Father *Riccioli* gives to this Shadow the length of about 213 Semidiameters of the Earth^a. According to M. *Maraldi's* Experiments in Opticks, the Shadow of a Globe exposed in full Sun-shine terminates at about 110 Diameters of the Globe^b; therefore the Length of the Earth's Shadow is about 110 Diameters of the Earth, that is, 330 thousand Leagues; and the Distance of the Moon from the Earth is only 90 or 100 thousand Leagues at most; since its least Distance from the Earth is about 53 or 54 Semi-diameters of the Earth, its mean distance 58, and its greatest distance 62. Therefore, the Shadow of the Earth, altho' it is conical, ought to eclipse the Moon.

Endox. Nevertheless the Eclipses of the Moon are not always observed, when the Moon is full.

Arist. They ought not to happen but when the Moon and Sun are in the opposite Nodes, or near to them, so that the Earth is directly

^a Almag. l. 5. c. 4. p. 294. n. 3.

^b Mem. de l'Acad. 1723. p. 13. 118.

between those two Luminaries. These Circumstances are necessary, in order to the Earth's hindering the Rays of the Sun from spreading themselves upon the Surface of the Moon. But these Circumstances do not happen in all full Moons; since the Sun (*s*) in his annual Revolution only passes twice thro' the Nodes of the Moon; that is, thro' the Points (*a, b*), in which the Orbit (*c*) of the Moon (*d*) cuts the Ecliptick (*e*) Fig. 32.

Eudox. Sometimes also, there is no Eclipse of the Moon in a whole Year.

Arist. If during a whole Year the Moon and Sun are not found at the same time in the Moon's Nodes diametrically opposite; it is not surprizing that a Year passes without an Eclipse of the Moon. But it may happen that during a whole Year the Moon and Sun never meet in the Nodes at the same time. For when the Sun by his Motion from the West toward the East arrives at one of the Nodes, it may be that the Moon, which ought to cut the Ecliptick in the other, has not as yet reached it, or has already past it. Therefore in a whole Year there may be no Eclipse of the Moon.

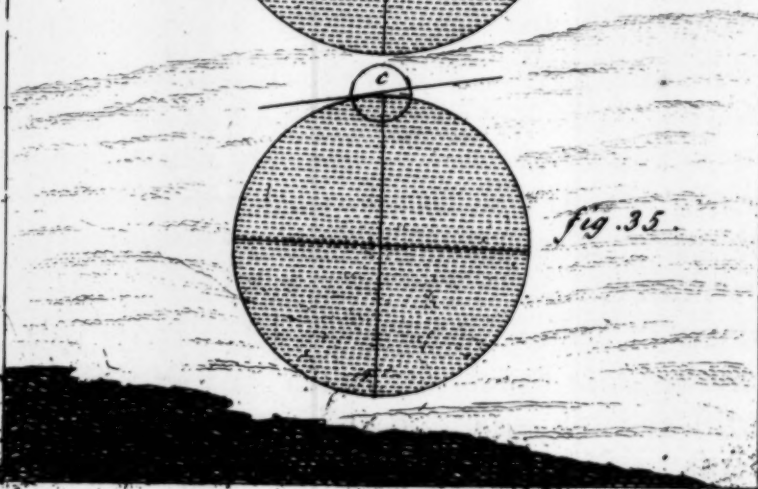
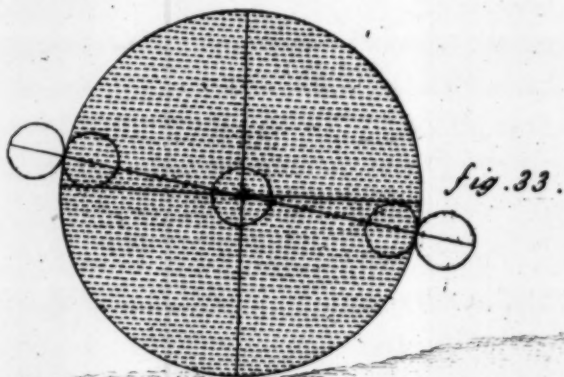
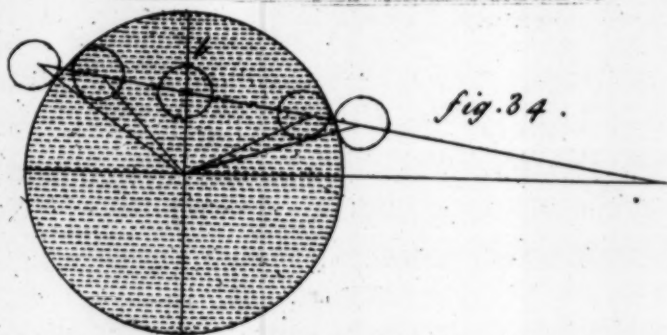
Eudox. When there happens one, it begins by the Eastern Limb of this Luminary*.

Arist. The Eclipse of the Moon ought to begin by that Limb which first plunges into the shadow of the Earth. The Eastern Limb of the Moon is first plunged into that, since the

* Ric. Almag. l. 5. p. 294. n. 3.

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Moon's Immersion happens by her moving from the West toward the East. This Motion alone makes her pass thro' the Node diametrically opposite to the Sun. Therefore the Eclipse of the Moon ought to begin by the eastern Limb.

Eudox. Sometimes the Eclipse is central (*a*), Fig. 33. sometimes total without being central (*b*), Fig. 34. sometimes partial (*c*), Fig. 35.

Arist. Sometimes the Moon cuts the Ecliptick in the Node, sometimes more or less near the Node, diametrically opposite to the Sun.

When the Moon is in the Node (*a*), Fig. 33. diametrically opposite, and her Center in the Line, which passes through the Center of the Earth and Sun; the Center of the Moon is in the Axis of the terrestrial Shadow, and the Eclipse is central. When the Moon (*b*), Fig. 34. is near the Node, wholly plunged into the Shadow, but without her Center being in the Axis of the Shadow, which surrounds her, the Eclipse is total without being central. When the Moon passes at a certain Distance from the Node, or from the Line, which runs through the opposite Nodes, the Center of the Sun, and the Center of the Earth, the Globe of the Moon (*c*), Fig. 35. is not wholly plunged into the Shadow of the Earth, and the Eclipse is partial.

Eudox. Even when the Eclipse of the Moon is total, the Moon scarcely ever disappears intirely *, she almost always appears more or less reddish; much after the same manner as we saw her lately in a total Eclipse, the 13th of *February* †.

Arist. To explain my Sentiment upon this Head, I shall distinguish with the Astronomers two sorts of Shadows, one a true Shadow, and another which they call Penumbra. Does a Place receive no sensible Rays of Light? This is a true Shadow. If it receive some sensible Rays, it is a Penumbra ‖. This being granted; if even then when the Eclipse is total, the Moon happens to be in a Penumbra, she ought naturally to be visible, and appear reddish. But the Moon, even then when the Eclipse is total, is in a Penumbra. For according to the Experiments of *M. Maraldi*, when a Globe is exposed in the full Sun-shine, the true Shadow does not extend above 15 or 16 Diameters of the Globe ‡, the rest is a Penumbra. Probably many Rays which graze upon the Borders of the Globe, being more compress'd upon the side which is illuminated, than upon the part of the Shadow, follow the Circumference of the Globe throughout some small Extension, much after the same manner as
Water,

* Hist. de l'Acad. 1724. p. 90.

† 1729.

‖ Riccioli Almag. nov. T. 1. l. 5. c. 5.

‡ Memoir. de l'Acad. 1723. p. 118, 119.

Water, which encounters the Piers of a Bridge, and take a direction in order to their proceeding to be re-united at some distance in the Shadow, still narrower, &c. to render themselves perceptible therein, or to render it less dark. Therefore the true Shadow of the Earth projects itself but about 15 or 16 terrestrial Diameters, that is about 45 or 48 thousand Leagues. The Moon is about 49 thousand Leagues farther distant, and the rest of the Shadow is a Penumbra. Therefore the Moon eclipsed is in a Penumbra, and that so much the brighter, because the Rays, which pass through the Atmosphere, proceed from all Parts with different Directions, caused by Refractions, to augment its Splendour. Therefore the Moon herself in a total Eclipse ought to be visible, as she is^c.

Eudox. But according to the Experiments of M. *Maraldi*, the Penumbra of opaque and round Bodies is surrounded with a Ring of a true Shadow^d. Probably because the Rays turned aside to produce the Penumbra, are not succeeded by others. This being granted; in the beginning, and at the end of an Eclipse, the Borders of the Moon ought to be more obscure, since they would be in a true Shadow; and on the contrary they are thereby more luminous.

^c Scheiner. Riccioli. T. 1. l. 5. c. 5. p. 306.

^d Mem. de l'Acad. 1723. p. 111, &c.

Arist. May not the Rays, which pass thro' the terrestrial Atmosphere, dissipate this annular Shadow, and make a luminous Shadow to be seen upon the Limbs of the Moon. In short, the Limbs of the Moon ought to answer to the Extremities of the Atmosphere; and these Extremities being composed of Air not so gross, and of Vapours not so condens'd, permit a greater number of Rays to pass, which are diffused upon the Limbs of the Moon.

Eudox. The Moon intirely eclipsed appears sometimes brighter, sometimes more obscure.

Arist. That is, because she is immersed sometimes more, sometimes less into the Penumbra, and answers to the Parts of the Atmosphere of unequal Density.

Eudox. We see the Moon in an Eclipse, successively assume different Colours.

Arist. The Atmosphere being unequally charged with Vapours and Exhalations, or charged with different Vapours, and different Exhalations in divers Parts, the Rays which pass entirely thorough it, since it is no where impenetrable to the Light, and come to fall upon the Moon, are sometimes more, sometimes less abundant; some of them more, some less broken; more or less separated, more or less directed by Refraction toward the Axis of the Shadow, and of the Penumbra.

Now,

Now, these Differences are so many Sources of different Colours *.

Eudox. In the same Eclipse, the Moon being seen from different Parts at the same time, seems to have different degrees of Obscurity, different Colours, as happened in the Eclipse of the 23d *December* 1703, observed at *Arles*, *Avignon*, and *Marseilles* †.

Arist. It is probable, that different Exhalations or Vapours, which do not cease to be unequally diffused in the Atmosphere, altho' the Season be very fair, cause those different Appearances in divers Parts at the same time. In short, those different Exhalations, and Vapours, are like Glasses unequally thick, and diversely dyed, thorough which the same Object appears different.

Eudox. But how comes it that during the Eclipse, the Moon sometimes disappears in a clear and serene Heaven °, before the time of setting, before the Twilight can make her disappear? How comes it, that being in a Penumbra, she disappears with respect to one place, without disappearing in regard of another, or that she disappears with respect to them at different times, as happened in the Eclipse of the 23d of *December* 1703?

* Riccioli, T. 1. l. 4. c. 6. p. 202. n. 12. l. 5. c. 5. p. 308. Taquet. Astron. l. 8. Tract. 3. n. 3. S. 3. Hist. de l'Acad. 1704. p. 61.

† Hist. de l'Acad. 1704. p. 59.

° Riccioli, T. 1. l. 5. c. 5. p. 305. n. 13. l. 4. p. 202. Schein. in Disquis. n. 26. Hist. de l'Acad. 1704. p. 59.

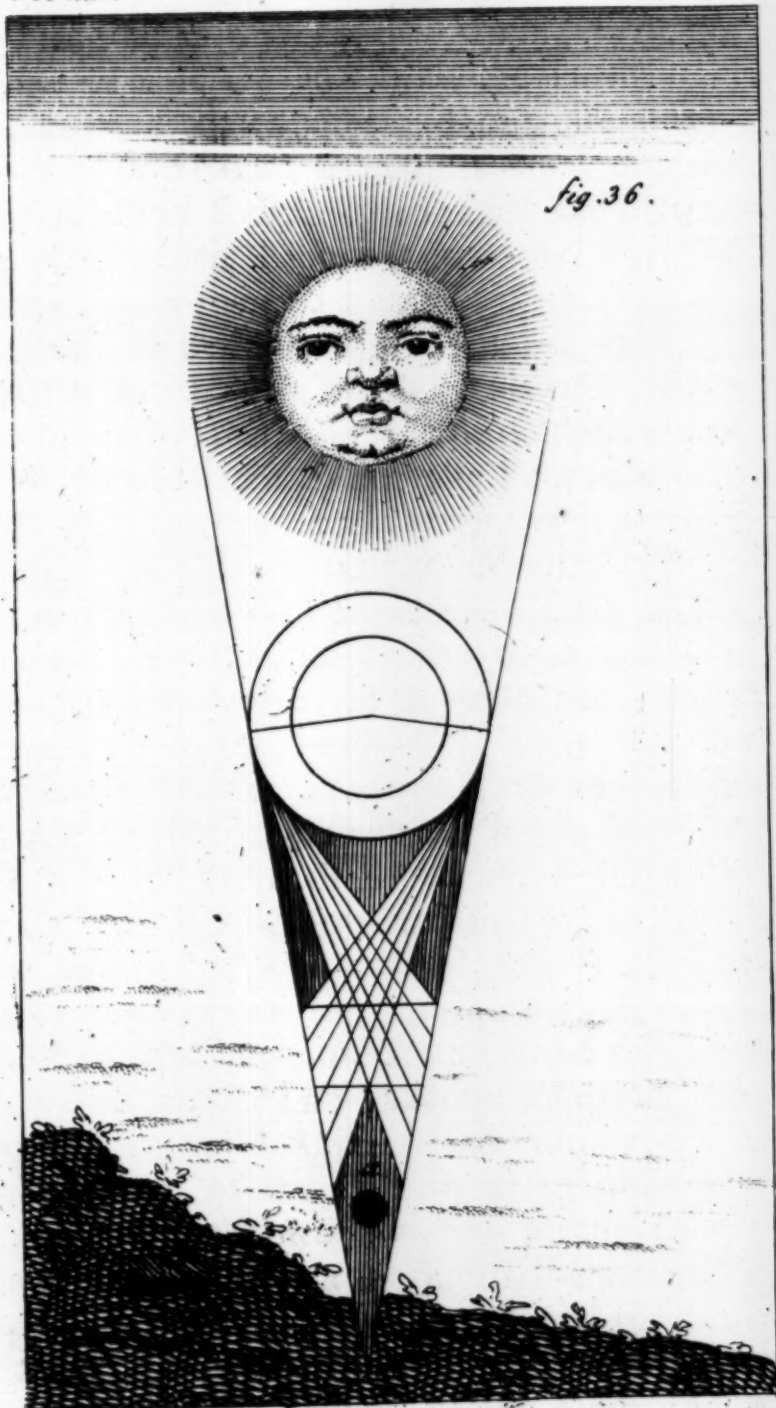
Arist. Probably, because in these Circumstances the interposed Vapours stopping or breaking the direct or reflected Rays, after an extraordinary manner, only leave the Moon, with respect to those who lose sight of her, the Colours of the liquid Ground which bears her.

Eudox. According to the Sentiment of Father *Riccioli* ^f, if the Moon be beyond the place (a), where the Rays broken by the Atmosphere, cross one another, and in the true Shadow of the Atmosphere, Fig. 36. she must in that case disappear. However that be, the Duration of the Eclipses of the Moon is ordinarily greater than that of the Eclipses of the Sun.

Arist. The Duration of the Eclipses of the Moon depends upon the Diameter of the Earth, which causes them. By the same reason, the Duration of solar Eclipses depends upon the Diameter of the Moon. Now the Diameter of the Sun is much greater than that of the Moon. The Diameter of the Moon is about 800 Leagues, and that of the Earth about 3000: whence the Duration of the Eclipses of the Moon, is ordinarily greater than those of the Eclipses of the Sun.

By the same Principle, the Eclipses of the Moon are more frequent than solar Eclipses. As the Diameter of the Earth is much greater than that of the Moon, the Earth ought oftner
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^f Almag. T. 1. l. 5. c. 5. p. 305.





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to hide the Sun from the Moon, than the Moon to hide the Sun from the Earth.

Eudox. Eclipses of the Moon are sometimes of two Hours, sometimes three, and the longest about four. The longest are central Eclipses, which happen when the Sun and Moon are in their Apogea.

Arist. When the Moon has less velocity, and has her Center in the Axis of a larger Shadow, the Duration of the Eclipse ought to be longer. But when the Eclipse is central, and the Sun and Moon are in their Apogea, the Moon has less velocity, because she is farther distant from the Center of her Vortex. She has her Center in the Axis of the Shadow, since we suppose the Eclipse central; and the Shadow is larger, for the Diameter of the Shadow is so much the larger, the farther distant the Sun is from the Earth. In short, if we bring a luminous Body near a Ball, greater than the Ball itself, the Shadow of it is conical and less. The more we remove the luminous Body from the Ball, the more the Diameter of the Shadow increases. The Shadow augments proportionally as the Rays, which come from the Extremities of the Sun to graze upon the Earth, approach nearer to two parallel Lines; and the farther distant the Sun is, the more they approach to two parallel Lines; and the more the Angle which they make diminishes. Therefore the longest Eclipses of the Moon ought

to happen, when they are central, and the Sun and Moon are in their Apogea.

Eudox. But when the Eclipse happens in the Moon's Perigeon, the Moon is found in a greater Diameter of Shadow, since the Shadow of the Moon is conical. Therefore the Eclipse ought to be of longer Duration.

Arist. If the Moon in that case runs over a larger Diameter of Shadow, she has more Velocity, being nearer the Center of her Vortex; and this excess of Velocity prevails over the excess of Diameter.

Eudox. The Eclipses of the Moon are of use for knowing the Longitudes or Distances, both northern and western.

Arist. The Moon being eclipsed, loses her Light in effect, since she has no proper Light. Wherefore the Eclipse begins and ends at the same time, with respect to the whole Hemisphere, which sees the Surface of the Moon. This being granted, whenever I know what Hour it was in an eastern or western Part when the Eclipse began to appear, I know the Distance from our Meridian, to that Place. For example, was it mid-night in any eastern Place, and only ten at night here? The Sun is two Hours sooner in the Meridian of that Country than in ours; he comes from thence to us in two Hours. Now in two Hours the Sun runs over 30 degrees of the Earth, since in 24 Hours he runs over 360. Therefore the Longitude of the eastern Place, which we
speak

fig. 25.

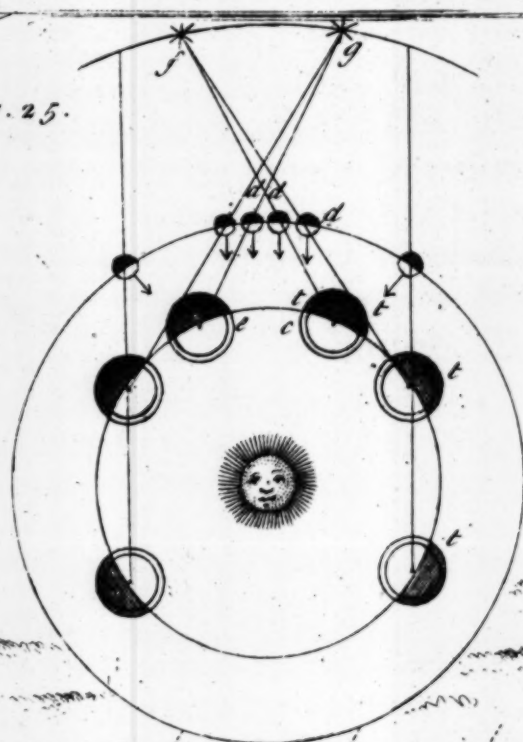
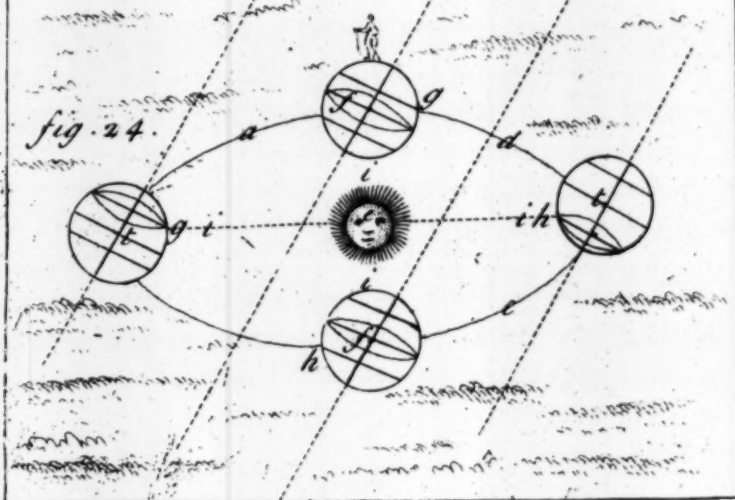
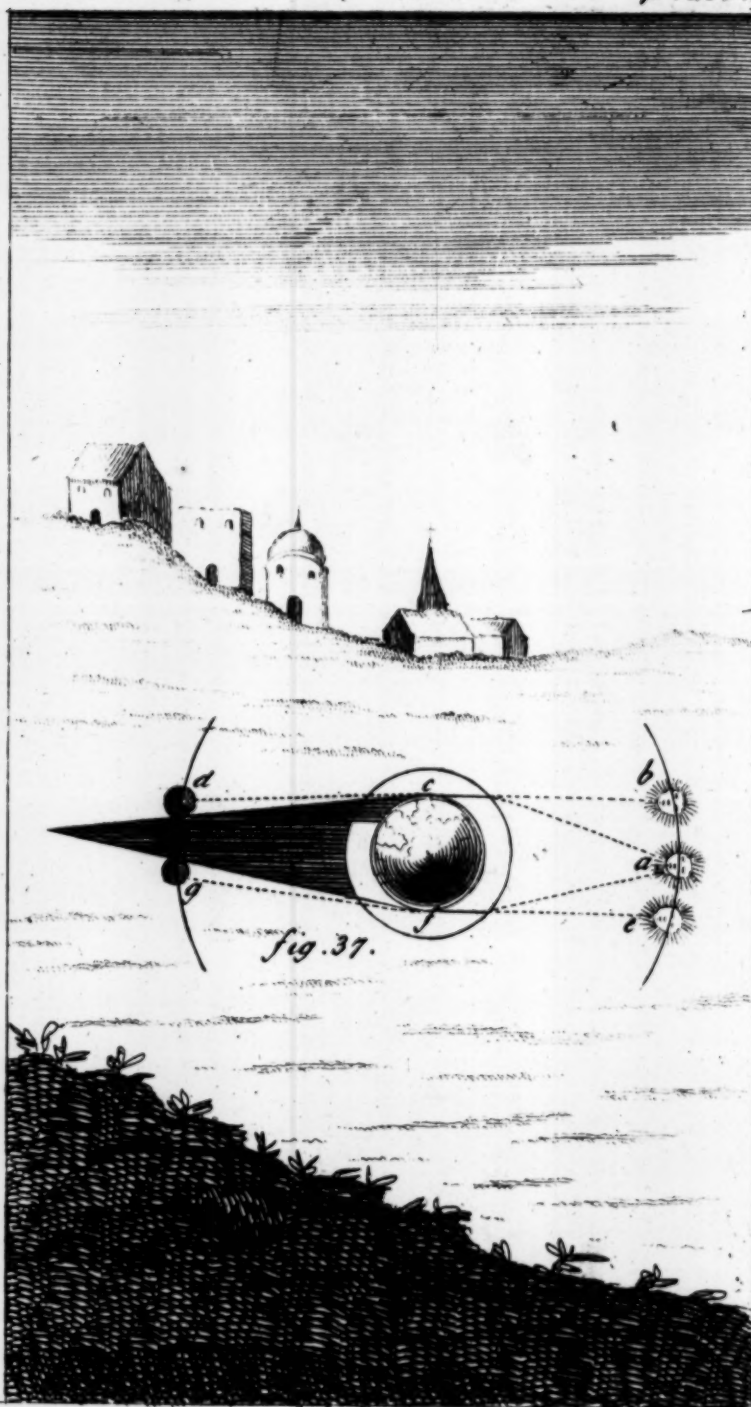


fig. 24.





speak of, or its Distance from our Meridian, is 30 degrees. I multiply the Leagues of one terrestrial degree by 30, and the Product is the Longitude, which I was seeking.

Eudox. A very rare Event, and which seems to overturn your Principles, is, that the Moon is eclips'd sometimes in the Sun's Presence, when these two Luminaries appear near the Horizon ^g. These horizontal Eclipses have been seen in divers Ages. They had seen of them at least in the time of *Pliny* ^h. They saw another the 17th of *July* 1590, at *Tubinge* ⁱ. A third was seen at *Tarascon* the 30th of *November* 1648. And a fourth in the Island of *Gorgone*, the 16th of *June* 1666 ^k.

Arist. The Moon and Sun are not in that case both actually above the Horizon, but the Refraction which elevates Objects, as we have said ^l, elevating those Luminaries, at least one of them, namely the Sun (*a*), Fig. 37. more than they are really elevated, makes them both to appear at the same time above the Horizon (*b c d*). By the same Principles, those who are above the inferiour Horizon (*e f g*), may see them there at the same time.

Eudox. Finally, the Eclipses of the other Planets, of the Satellites, and of the fixt Stars, happen

^g Mem. de l'Acad. 1711. p. 234.

^h Pliny, T. 1. l. 2. c. 24.

ⁱ Kepl. Astron. Opt. p. 136. Riccioli, T. 1. l. 5. c. 5. p. 307.

^k De l'Eclip. horiz. de Lune 16 Juin 1666. J. des Scav. p. 426.

^l 20 Convers. Vol. 2.

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happen according to the same Principles; and the Knowledge of the Difference of the times when these Eclipses, especially those of the Satellites of *Jupiter*, which happen very often, are seen from divers Parts, makes us know the Difference or Distance of Meridians, and consequently the Longitudes of divers Climates. If two Observators see the same Emer-sion of the fourth Satellite of *Jupiter*; suppose from two different Places they see this Satellite come out of the Shadow of its primary Planet; suppose it be mid-night in one of these Places, and two Hours after mid-night in the other: this will be more easterly by 30 degrees.

Comets are celestial Bodies, which more seldom appear. Accordingly they are probably less known.

Arist. You will favour me upon this Head with what seems most probable to you; and I shall be satisfied.



CON-



CONVERSATION XX.

Upon COMETS.*Arist.*

RAY, *Eudoxus*, what are the Appearances of Comets? What Reality is there in those Phænomena? What are the Causes of their Appearances? Have People reason to be alarm'd at the sight of a Comet, notwithstanding the Discourses of Philosophers?

Eudox. They observe in the Heaven from time to time new Stars, as it were, or rather new Planets, surrounded with a sort of Atmosphere, sometimes less, sometimes more bright, sometimes smaller, sometimes greater, carried towards divers Points of the Heavens, with Differences of Velocity and Elevation; and this is what they call Comets*. Father

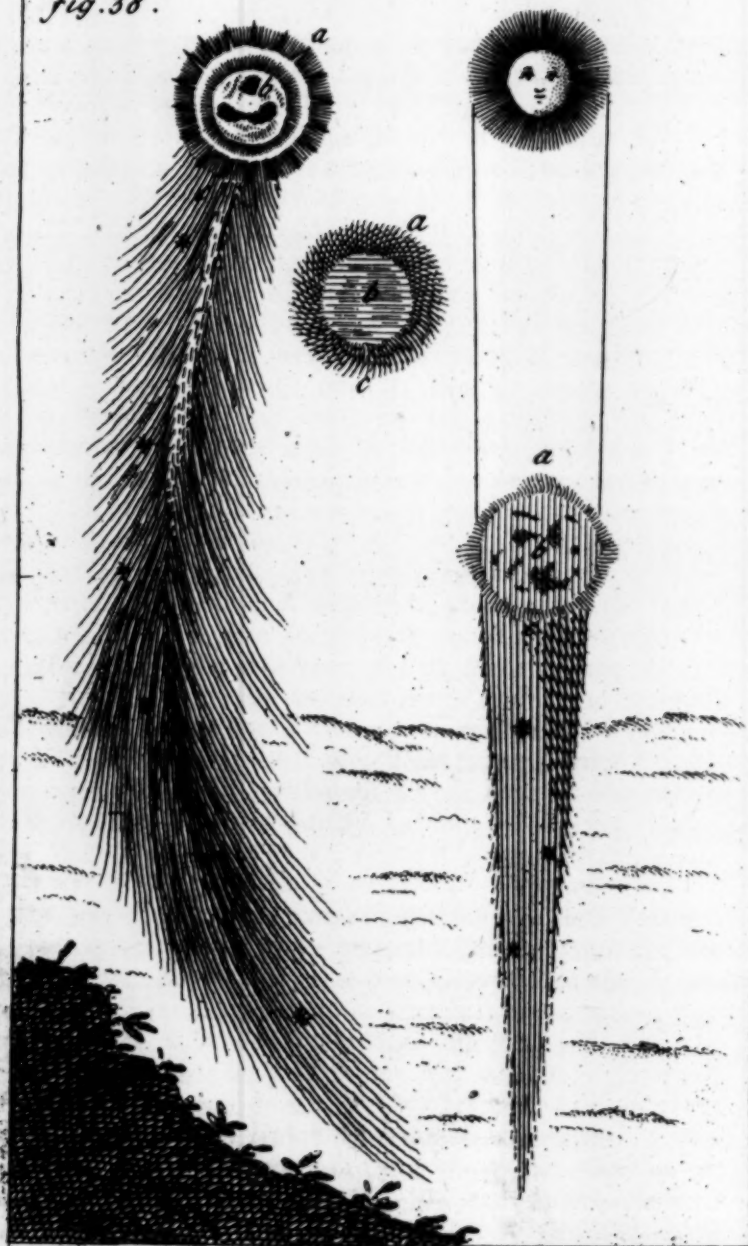
Riccioli

* The Comets seem to be the most extraordinary Appearances in Nature, and to have been as yet least accounted for; having been thought very irregular, and subject to no certain Laws. But from later Observations, and more strict Enquiry, even *Those* also are found to move in very regular Curves, and to be situated in the best Position, with respect to each other; and to be of considerable use. They appear to be very numerous; which

Riccioli talks of 154 Comets observed from the Year 480, before the Birth of Jesus Christ, to

which Consideration alone is sufficient to suggest to us, that there must be great occasion for them in such a System as this. They are a kind of Planets, being large and dense Bodies, with very gross Atmospheres, and are capable of emitting great quantities of Vapours, as appears from the Bigness and Length of their Tails; and they revolve about the Sun in very large Ellipses, of which the Sun is one of the Focus's. From all which we may collect some of their principal Uses also. The Body of the Sun must necessarily be diminished by that vast quantity of Light that is perpetually emitted from it, and therefore in time will decay and stand in need of a supply of fresh Materials for Fuel. These may be had from Comets: For by Observation we find, that they sometimes approach very near the Body of the Sun, and consequently must at last fall into it. For by reason of their prodigious Swiftmess at that Time, and the Density of the Sun's Atmosphere, their Motion must be somewhat resisted and retarded; so that they will revolve nearer and nearer till they run into it. This may also be promoted by the Gravitation of other Comets, when they are *in Aphelio*; because they move slowest in that part of their Orbit, and consequently will be retarded by such Attraction, and an Alteration be produced in the Figure of their Orbs. But before they come to this, there are very good reasons to think that they are of great Benefit to the Planets. Experience shews us, that the Water in the Sea continually decreases, and the dry Ground continually encreases; the great quantity of Vapours which are exhaled from thence, being converted into Nourishment for all kind of Vegetables, which when they come to putrify, are in good measure turned into dry Earth, so that by this means a great part of the Liquid is destroyed: All which Defects are probably supplied from the Tails of Comets: For these consisting chiefly of such Vapours, and spreading themselves to an immense Distance through the heavenly Spaces, may fall by their own Gravity into the Atmospheres of the Planets, and there be condensed, and turned into Water and other Substances. To this we may add, that the finest and most spirituous part of our Air, which is the most subtle, and the best, and is necessary to preserve Life in every Thing, may with good reason be thought to proceed chiefly from the Comets. And from all these things put together, it is manifest why the Comets are not, like the Planets, confined to the *Zodiack*, but cut the *Ecliptick* at all Angles, and move freely

fig. 38.



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to the Year 1618*. Since that time many have been seen, namely in 1652, 1665, 1682, 1689, 1699, 1702, 1706, &c.

In a Comet we may distinguish the Body, the Atmosphere, the Degree of Light, the Bigness, Direction, Latitude, Velocity, and Elevation of the Comet.

When one observes a Comet (*a*), Fig. 38. one remarks therein a Light (*b*), more lively than that of the Atmosphere (*c*), which surrounds it, but very small in comparison of this Atmosphere †; and this is probably the Body of the Comet.

The Atmosphere which surrounds it in form of Hair, and seems sometimes to follow it in form of a Tail, is a Species of luminous Cloud, still diminishing in Splendour towards the Borders^a, and transparent even in that part where it is most condens'd and thick, since one sees the fixt Stars thorough it^b.

The Light and apparent Bigness of Comets are sometimes like those of a small clouded Star^c, sometimes like those of *Jupiter*. We have

freely thro' every part of the Heavens, viz. that when they are at the greatest Distance from the Sun, and move most slowly, they might also be at the greatest Distance from each other, and so disturb one another as little as possible by their mutual Attraction. *Dr. John Clarke's Sermons at Boyle's Lect.* Vol. 1. p. 115.

* Almag. l. 8. f. 1. c. 3.

† Hist. de l'Acad. 1708. p. 104. M. 1707. p. 323. M. 1723. p. 255, 290.

^a Hist. de l'Ac. 1706. p. 104.

^b Ibid. 1723. M. p. 255, 290.

^c Ibid. 1706. p. 104.

have seen through a Glafs, says *M. Cassini*, Comets whose Discus was as big, pure and clear as that of *Jupiter*. Such was the second Comet of 1665, and that of 1682^d. *Tycho* had seen some much like them in 1585, and 1590^e. Sometimes Comets appear like a great Star; such was that which appeared in the Months of *February* and *March* 1702^f, observed at the Mouth of a River of *Mississipi* in *America*, by *M. le Sueur*. *Seneca* speaks of a Comet as big as the Sun^g.

Comets have different Directions in their Motions. Some come from East to West, as the second of 1702^h. Others come from North to South, as those of 1689, and 1699; or from South to North, as those of 1472, and 1556ⁱ. That of 1707 mov'd almost directly from South to North, from Pole to Pole; but about the end it returned from North to South, and appear'd to move obliquely from the West toward the East^k. Comets, which move from East to West, are more frequent than those which move from one Pole to another^l.

The Comet of 1706, might be 55 degrees distant from the Equator*.

Comets

^d Mem. de l'Ac. 1699. p. 39.

^e Taq. Astron. l. 8. tr. 2. p. 331.

^f Hist. de l'Acad. p. 67. M. p. 216.

^g L. 7. Nat. Quæst. c. 15.

^h Hist. de l'Ac. 1702. p. 67. 1706. p. 104.

ⁱ Ibid. 1708. p. 100.

^k Ibid. 1708. p. 98.

^l Ibid. 1708. p. 101.

* Ibid. 1706. p. 104.

Comets in their different Directions seem to describe an Arc of a great Circle, whose Plane passes thro' the Center of the Earth^m. While those, which are visible, run over the Arc of their Circle; we see several of them augment equally from day to day, both in Velocity and apparent Bigness, to a certain degree, like Planets which approach their Perigeon; and after that, during an equal time diminish equally in Velocity and apparent Bigness, like Planets which remove from their Perigeon; and continue and diminish after that manner until they disappear entirelyⁿ. In 1708, M. *Cassini* wrote of six Comets since 1580; which after their first Appearance had continually augmented in apparent Velocity and Bigness; but in unequal times, the shortest of which had been ten Days, and the longest 43°.

There is a Point therefore in which Comets appear biggest, and their Motion seems to have the greatest Velocity. Their Motion is equal, or almost equal, at equal distance from this Point, both on the one side, and the other, as was remarked in the Comet of 1698^p; and this Point is call'd the Perigeon of the Comet. The Comet of 1723, had the last day of its Appearance only a 60th
part

^m Mem. de l'Ac. 1699. p. 36. 1706. M. p. 92.

ⁿ Ibid. 1724. p. 376.

^o Hist. de l'Ac. 1708. p. 101.

^p Mem. de l'Ac. 1699. p. 37.

part of the Motion, which it must have had in its Perigeon^q.

Finally, the Elevation of all Comets is not the same, since according to the Observations of Astronomers, some of them have a certain Parallax, greater or smaller, and others have none at all. They gave six degrees of one to a Comet of 1472, which placed it six times nearer the Earth than the Moon, since the Moon has only about one degree of Parallax. But those six degrees do not seem very probable. The Comet of the Month of *April* 1702, appear'd to M. *Maraldi* to have an horizontal Parallax of 13 minutes; which gives it a distance from the Earth about five times greater than that of the Moon^r. The Comet of 1707 had only two Seconds of Parallax at most^s. That which was observed the second of *March*, the same Year, had no perceptible Parallax^t. This being granted; Comets, at least a great number of them, cannot be less elevated, or scarcely less elevated, than *Mars*, the last Planet in which they find any Parallax; a Parallax, I say, difficult enough to be verified^u. They are not above the fixt Stars; since the fixt Stars are eclips'd by them. The Comet of 1706 hid a Star^u. M. *Cassini* places
the

^q Mem. de l'Acad. 1723. p. 254.

^r Hist. de l'Acad. 1702. p. 68.

^s Mem. de l'Acad. 1708. p. 330.

^t Ibid. 1702. p. 102.

^u Ibid. 1699. p. 39.

^u Ibid. 1706. p. 91.

the Comets of 1652, and 1680, between the Circles of *Venus* and *Mars*, above the Parallax which he thought he found in them^v. These are the Appearances of Comets; what is there of reality in them?

Arist. I fancy I perceive it in the true Explanation of their Phænomena.

Eudox. Do you believe that they are Exhalations of the Earth kindled in this immense Liquid, in which the Luminaries swim, fortuitous and fleeting Productions?

Arist. That is not probable; why? 1. Sometimes the Exhalations of the Earth would ascend, at least to the distance of 15000 Leagues, as in the Comet of 1472, if it is true that it had six degrees of Parallax, since the Moon, which has only one, is about 90 or 100 thousand Leagues distant. Sometimes the Exhalations of the Earth would be found at the distance of about 500000 Leagues, as in the Comet of the Month of *April* 1702, which appeared to have 13' of Parallax, or to be five times more elevated than the Moon; sometimes the Exhalations of the Earth would be elevated to an inconceivable distance; seeing there are Comets, which have no Parallax, as the first of 1702, and yet *Mars* has one. But it is no way probable that the Exhalations of the Earth are elevated to so prodigious a distance. Therefore, &c. 2.

^v Mem. de l'Acad. 1699. p. 72.

2. We see Comets, whose Discus is as round and clear as that of *Jupiter*, such as that of 1681; other Comets as big as a large Star, and without any Parallax, such as that of *March* 1702. These Comets, in order to appear so perceptibly at so prodigious a distance, ought, I think, to have a Globe as great as that of the Earth at least. Pray, how should the Earth furnish so many Globes of inflammable Matter, as big as itself?

Upon the same Principles, Comets are not Exhalations that issue out of Planets.

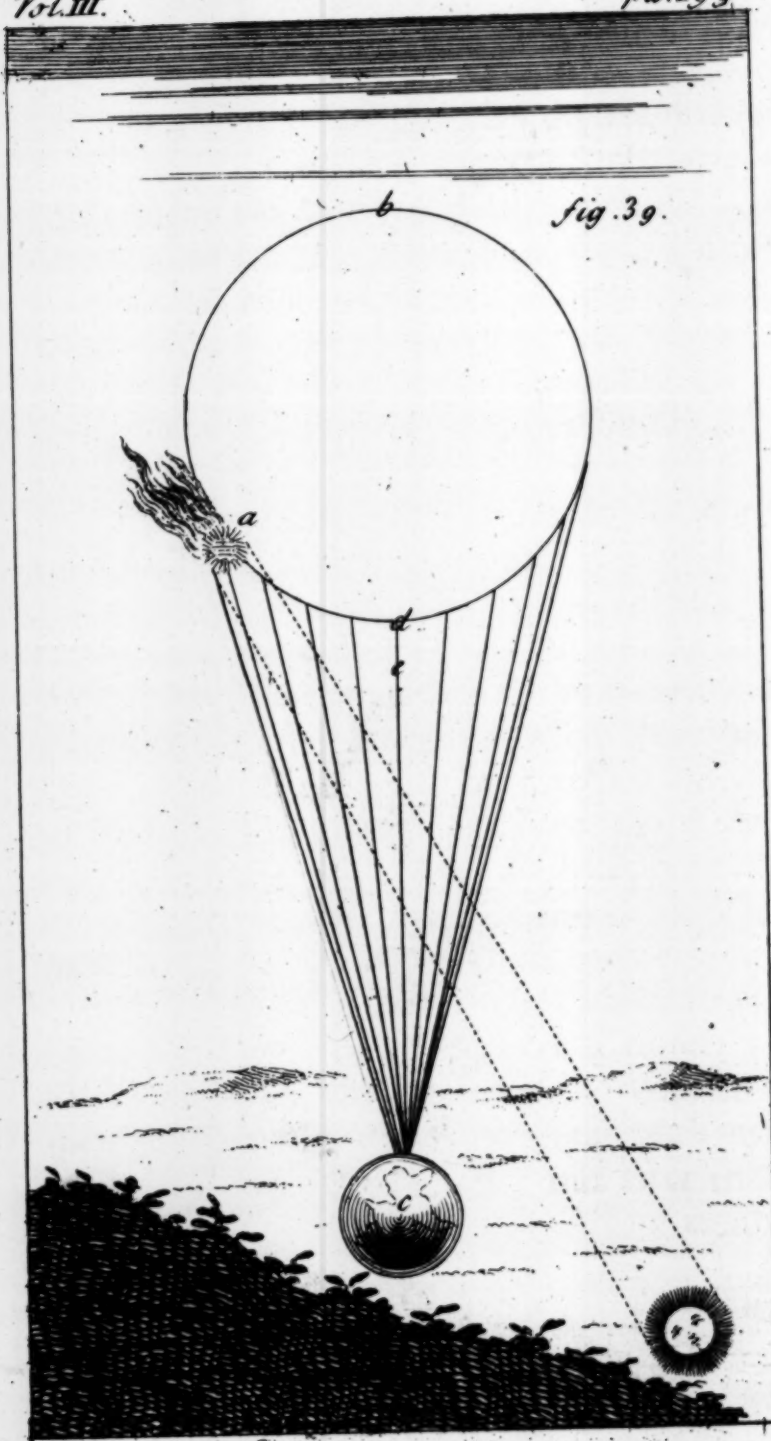
3. Finally, we see Comets augment at the same time, both in velocity and bigness, sometimes during 10 days only, sometimes during more than 40; and after that, to diminish in velocity and bigness, in the same *ratio*. Now, did this perfect Conformity of these apparent Augmentations and Diminutions happen in kindled Exhalations, in fortuitous and fleeting Productions, inflamed suddenly, and by chance; the kindled Productions would successively increase and diminish in bigness: but for all that, they would neither increase nor diminish in velocity, as they do. They ought to take the Direction of the Vortex, and yet they often have contrary ones. In being kindled, they would become more rare; being more rare, they would more easily obey the Direction of the Fluid, in which they float: and yet oft times the more they appear to be inflamed, and to increase in
Splendour

Splendour and Bigness, the more swiftly they move against the Direction of this Fluid, as the second of 1702. Therefore Comets are not fleeting and inflamed Productions. In short, they send forth no Rays, as Bodies ordinarily do which shine of themselves: and would fortuitous and fleeting Flames appear to the Eye three, four, and sometimes six Months?

Eudox. What then are Comets?

Arist. It is probable that Comets are solid, durable Bodies, as old as the World; Planets, which have only one part of their Course or Circle within the reach of our View. For in a word, as we have already prov'd, Comets are not Exhalations, fortuitous and fleeting Fires, suddenly kindled in this vast Liquid, in which we see them. Therefore, &c.

Eudox. If Comets are regular Bodies, or whose Course is regular, as they have only a foreign Light, since they do not twinkle, and their Atmosphere has different Figures, different Aspects, according to their Situation with respect to the Sun, they must be solid Bodies, Planets. Now, Comets are probably regular Bodies, such whose Course is regulated; for it is probable, that they have their Returns, or that they appear again after a certain time, a certain number of Years. If we find that a Comet has at one and the same time both the same Nodes in the Ecliptick, and the same Inclination to the Ecliptick, and the



diminish in the same time, both in bigness and velocity. How shall we explain this Phenomenon?

Eudox. Let us suppose, with M. *Cassini*, that a Comet (*a*) describes a great Circle (*b*), excentrick to the Earth (*c*), so that it does not contain it, and whose inferiour part, which prolonged, would cut the Center of the Earth, is visible, while the superiour part proceeds to lose itself in the Heavens. The Point (*d*) of the inferiour part, nearest the Earth, is the Perigeon of the Comet. Let us now conceive the inferiour part of the Circle divided into equal Arcs. To all these Divisions let us draw right Lines from the Center of the Earth, or from the Eye of the Observator. These strait Lines will make unequal Angles, the equal Arcs contained between these Lines being unequally inclin'd to these Lines, some more, and others less. The Angles will be so much the greater, as they are nearer to the Perigeon (*d*), or to the Perpendicular (*e*) drawn from the Center of the Earth to the Center of the Orbit, Fig. 39. For the Arcs being more parallel to the Horizon, will render those Lines more diverging; and consequently the Arcs will appear so much the greater, the nearer they are to the Perigeon, since they will be seen under greater Angles.

Arist. This being granted; 1. A Comet, which descends towards the Perigeon, ought

to increase in apparent bigness, because it approaches to the Earth. 2. A Comet which descends ought likewise to increase in apparent velocity, if proportionally as it descends, it describes in equal times Arcs sensibly greater; but in equal spaces of time it describes Arcs sensibly greater; since it approaches to the Perigeon, and the Arcs appear so much the greater, the nearer they are to the Perigeon. By the same Principles, a Comet ought to diminish in apparent bigness and velocity, proportionally as it removes from the Perigeon, since it continually removes from the Earth, in describing Arcs sensibly smaller in equal spaces of time. Therefore this Phenomenon may be reconciled with Physicks.

In short, the nearer the Arcs are to the Perigeon, the more distinctly are the parts of those Arcs discerned, being seen by more distinct Rays. The farther distant the Arcs are from the Perigeon, the less distinctly are the parts of those Arcs seen, because the Arcs becoming sensibly, or almost sensibly perpendicular to the Eye, the Rays which come from every one of their parts to the Eye, penetrate, as it were, one another, and are confounded in some measure, without making different Impressions upon the Retina. Wherefore, when a Comet runs through the Arcs, which are farther distant, the Eye does not discern at all, or less discerns its Passages from one Point of the Orbit, to another;

other; the nearer the Comet approaches the Perigeon, the better the Eye discerns its Passages from one Point to another: now, the more we discern the Points of the Orbit run through in a certain time, the more velocity the Body seems to have, which runs through them; since the apparent velocity is measured by the space sensibly run through. Therefore the Comet ought to encrease in apparent velocity and bigness as far as the Perigeon, and after that by a contrary reason to diminish both in apparent velocity and bigness.

Eudox. But sometimes Comets only diminish in bigness and velocity after their first Appearance.

Arist. That is, because they have not been perceived before they were in their Perigeon; because the Clouds, Twilights, or Rays of the Sun being too near, hindered them from appearing.

Eudox. At least in the beginning of their first Appearance, we ought, I think, sometimes to see in them the same bigness and velocity, which they have when they cease to be visible; since they are at the same distance from the Perigeon; and this is what *M. de la Hire* says has never been seen.

Arist. Probably because Comets, by reason of Clouds, Twilights, Proximity of the Sun, or Inadvertency of Astronomers, have

never appear'd the first moment that their distance permitted their being seen.

Eudox. Comets have no Radiation, or Scintillation.

Arist. Because they are solid Bodies, which have only a borrowed Light, too much weakened by Reflection to send forth Rays at so great a distance.

Eudox. Nevertheless the whole Disk of the Comet appears always enlightened.

Arist. Because the whole Disk, which faces us, is always enlightened by the Rays of the Sun, on the account of its great Elevation.

Eudox. But why do Comets, or at least some of them, appear only two, three, four or six Months at most, in 30 or 40 Years, since they are Planets whose whole inferiour Disk faces us at the same time it faces the Sun?

Arist. 1. Probably because their Circle is immense, and they are only visible in the inferiour part of their Circle. 2. Clouds, Twilights, and their Proximity to the Sun, may often hinder their return from being perceived.

But pray, *Eudoxus*, what can give Comets directions from Pole to Pole, and also from East to West, contrary to the Torrent * of the Vortex, in which the Planets are carried, and force them to follow those Directions?

Eudox,

* See Notes Convers. XV. *supra*.

Eudox. Currents which issue out of other Vortices, or the Impetuosity of other Vortices, and other Stars, may, I think, give them both those Directions, and force them to follow them, without any sensible Diminution of Motion. Besides, the Satellites of *Jupiter* and *Saturn*, when they are retrograde, or in the inferiour part of their Circles, are carried against the Direction of the general Vortex by their particular Forces, or by those of their proper Vortex. May not Comets, by the same Principle, seem to be carried for some time contrary to the Torrent of the Vortex of the Planets? The Impetuosity which precipitates them into this Fluid, serves to preserve their contrary Direction; after that they ascend again, meeting with less Obstacle in the superiour part of their Circles. Hence toward the end of their Appearance we see them often turn aside toward the East. In a word, it is probable that many Comets which have no Parallax, are above *Saturn* itself, in irregular Currents, caused by the Vicinity of divers Vortices; and thence proceed the different Directions which are observed in different Comets.

Arist. It naturally follows from our Conversation, that we ought not to be alarm'd at the sight of Comets, as People were in former times; since we have prov'd Comets to be regular Bodies, Planets.

Eudox.

Eudox. "While the Heavens were little observed, Comets were rare, says *M. de Fontenelle*^b, and only those were seen which were very visible; whose bigness and figure, joined to their rareness, struck a Terroure in all Places. At present, while the Eyes of a great number of skilful Astronomers are always open to explore all the Corners of the Heavens, Comets become common, and Persons grow familiar to them, so as to call them Planets." *Sir Isaac Newton's* System seems naturally to present itself, and deserves some Attention.

^b Hist. de l'Acad. 1702. p. 68.





CONVERSATION XXI.

Upon Sir ISAAC NEWTON's System.

Eudox. **T**RULY, *Aristus*, we have taken too much pains to give to Planets and Comets directions approv'd by Philosophy. Had we not done better to have begun with annihilating this vast Fluid, in which they make the Luminaries swim? The Planets would have room enough in an immense Vacuum. The Planets and Comets suspended by the Hand of the Creator in the Vacuum, and placed, those in different Circles round the same Center, and these in excentrick Circles, unequal and differently directed; would peaceably make their Revolutions; no Obstacle would trouble them, nor disquiet Philosophers. Comets needed only to follow their first Direction, and wander without any Irregularity, some toward the East or West, and others Northward or Southward.

Arist. This System would be commodious enough; an air of Novelty would recommend

mend it ; perhaps it would want nothing but a little more Probability and Truth.

Eudox. Notwithstanding, this Hypothesis is true, according to Sir *Isaac Newton* ; and this great Man did not question but that there were imaginary Spaces in the World itself *. Neither the subtile Matter, nor the ethereal Matter, with which M. *Descartes* made Heaven and Earth to be over-flowed, could be digested by this famous *Englishman* ; and far from looking upon this fine Matter as the Soul of the World, he thought it only proper to cause a general Stagnation in the Universe. Thus he gives it no quarter, and concludes with rejecting it entirely.

Arist. I should not suspect Sir *Isaac Newton* to have allowed himself to be surprized, by a secret pleasure of establishing a System upon the Ruins of a famous Hypothesis. The Authority of so great a Name is to be respected ; and he deserves the Honour which *England* did him, and itself, by honouring Learning in a learned Man. But Authority, I must own, does not seem here wholly consonant with Philosophy. Allow me to declare my Sentiments upon this Matter.

The Laws of Nature observed upon the Earth, seem to me to be observed in the Heavens, which are within reach of our Senses. This Uniformity in so great a piece of Workmanship, is worthy both of the Wisdom and Simplicity of its Author ; it bears the

* See Notes Convers. 5. Vol. 1.

the Impression of his Attributes. Hence, we see, for example, that which spreads Dark-ness and Light over the Earth, also spreads Light and Dark-ness over the Heaven and Planets. Now upon the Earth, a Body moved circularly, whenever it is at liberty, or is not detain'd by some external Matter, describes a right Line, which removes it from the Center of its Motion. A Stone thrown out of a Sling becomes visible to the Eye ; if the Stone preserved its circular Motion, it would be a prodigious thing, a Miracle. This being granted ; here is the Reasoning which presents itself to my Mind.

Planets and Comets have always a circular Motion ; this is agreed on. But if the Space, in which those Luminaries make their Revolutions, were void, they ought long ago, instead of moving circularly, to have described right Lines towards the Region of the fixt Stars ; since among Bodies, which are within reach of our Senses, a Body which moves round, passes off by a right Line *, whenever
it

* It is now apparent from the most exact Observations of the Phenomena of the celestial Motions, that they are so placed in the most free and open Spaces, as to revolve about certain Centers, by a Force compounded of *Gravity*, and a *projectile Motion in straight Lines*, which were impressed upon them by God at the Beginning; viz. the larger Planets about the Sun, and the Satellites or Moons about their own Planets : this may be explained in a few words.

Because all Matter gravitates towards all Matter, in a certain Proportion to the Quantity and Distance (*Confer Notes Conversat. XV. Vol. 1.*) And because the Body of the Sun is much larger
than

it is at liberty, or is not stopt by the resistance of some external matter; the Luminaries ought long ago, at the rate of their Motion, to have wandered among the fix'd Stars, or rather to have served for Nourishment to some Stars which would have swallowed them up.

Eudox. Oh! have a care, *Aristus*; the Gravity which gives the Planets a continual tendency toward the Center of their Motion, retains them in their Orbits, and hinders them from going aside, notwithstanding the liberty they would be at, of so doing in a Vacuum. Therefore Gravity is a wonderful means of explaining

than all the Planets put together; it is manifest that if all the Planets were at rest in their proper Places, they would by their own Gravity be carried directly into the Sun.

Now because the Case was thus, and all the Planets *gravitated* towards the Sun, God impressed upon them a *projectile Motion in straight Lines* also; in such a manner as to be perpetually pulled from these straight Lines, and kept from flying off from their Orbs by Gravitation, and at the same time to be perpetually urged on by that *projectile Motion*, lest they should fall into the Sun by the force of their Gravitation: so that by these two Forces acting together, they must necessarily be carried in some curved Line about the Sun; just as a Stone turned about in a Sling, by being perpetually hindred by the String from flying off, all the while that it endeavours to recede from the Center by its projectile Motion, describes a Circle. If the *projectile Velocity* be so exactly adjusted to the *gravitating Force*, as to balance each other in such a manner that the Planet shall neither approach nearer to, nor recede farther from the Sun; in this Case, the Planet will describe an exact Circle about the Sun. And it appears by Observation, that in the Revolutions of the Planets about the Sun, and the Satellites about the Planets, that the Squares of their periodical Times are as the Cubes of their Distances; therefore the gravitating Force by which they are retained in their Orbs, is every where reciprocally as the Square of their Distances.

And

explaining the Revolutions of Comets and Planets, without the help of etherial Matter.

Arist. But, *Eudoxus*, if Gravity continually gives Planets a tendency which directs them toward the Center of their Revolution, what hinders them from uniting with it, while betwixt them and this Center there is nothing at most but a Vacuity where Sight is lost, an immense nothing? The Inhabitants placed by fine, fertile, and bold Imaginations, in the Moon, *Jupiter* †, and *Mars*, would probably have long since come to honour us with a visit. Or rather they would have been, as well

And the same holds true, if they are moved in any Conick Section; because there is such an affinity between a Circle and these Sections; and a Circle may be made to pass into an Ellipsis, and an Ellipsis into a Parabola, and a Parabola into an Hyperbola.

And because the Motion of a Planet is retarded as it recedes from the Sun, and accelerated as it approaches towards the Sun, the Planet always *describes equal Areas in equal Times*.

This is the Nature of the Motion of all the Planets, as well the primary Planets about the Sun, as the Moons or Satellites about their own Planets; except that they are moved in Ellipses not much different from Circles.

But the projectile Motion may be so very quick, that the Ellipsis, in which the Planet is carried, may become of a very great Length, and very excentrick: and a Planet moving in such an Orb is called a *Comet*.

Nay, the projectile Motion may possibly be so much quicker still, that the Planet may be carried in a Parabola, so as never to return again; but we do not know of any such Motion in Nature.

Upon these Principles, the illustrious Sir *Isaac Newton*, in his wonderful Book of the *Mathematical Principles of Philosophy*, has explained the true System of the World, and shewn the true and adequate Causes of all the Celestial Motions, almost beyond the Genius of a Man. *Clarke's Rohault*, Vol. II. p. 74, &c.

† Riccioli *Almag.* T. I. l. 4. c. 2. p. 187. Huygen, *Entretiens sur la pluralité des Mondes*, par M. de Fontenelle.

well as we, a prey to the devouring Flames of the Sun.

Eudox. May we not suppose that the Stars at first receiv'd two Directions, the one perpendicular, which carries them toward the Center of their Revolution; and the other Horizontal, which removes them from it; and that in order to comply with the two Directions, they chose to describe a Circle?

Arist. On this Supposition, the Planets at first ought to have described a Diagonal, a right Line; as a Billiard-Ball, which upon a free Plane receives two Impressions in order to describe a Square, describes a Diagonal, a right Line; that it may comply with both Impressions: and a right Line would naturally enough carry a Planet into some fix'd Star, which would consume and reduce it to Powder.

But pray, *Eudoxus*, whence would the Gravity * of Planets arise in a Vacuum? Should

* Gravity or the Weight of Bodies is not any accidental Effect of Motion, or of any very subtile Matter, but an original and general Law of all Matter impress'd upon it by God, and maintained in it perpetually by some efficient Power, which penetrates the solid Substance of it; for Gravity never is in proportion to the Superficies of Bodies, or of any Corpuscles, but always to the solid quantity of them. Wherefore we ought no more to enquire how Bodies gravitate, than how Bodies began first to be moved.

Hence it follows, that there is really a *Vacuum* in Nature, and that it is much the greatest part. For since Gravity is an universal Affection of Matter, if we suppose the World to be full, it would follow, that all Bodies would be equally heavy: Which is very absurd.

This

Should it be from the nature itself of Bodies? But Bodies; which in their natural estate are only a Portion of modified Matter, have of themselves no efficacy, no force, no bias to one Direction more than another; they are most indifferent. Thus whenever you give them a Direction, you see them follow it exactly, until some Obstacle force them to quit it; and they follow it with so much the more constancy, the less the Obstinacy is with which the Obstacle resists. Should it be from the motion, stroke, or impulsions of some foreign Body? But in the Vacuum, there is no superiour Body, which could drive inferiour Bodies towards their Center. Should it be precisely from the Will of God? But it is not the Will of God that the Bodies, which surround us, descend towards their Center, unless the Stroke and Impulsion of a foreign Body be some way concerned in it. A polished Marble continues

This being laid down for the Nature of Gravity; it will follow, that the Planets, if they have once impress'd upon them by God, the most simple projectile Motion in straight Lines, will revolve about the Sun, as we see they really do in Circles or Ellipses, without the help of Vortexes.

Hence it likewise follows, that if any very great Collection of fluid Matter be gathered together upon the Superficies of the Earth, it must flow backward and forward according to the various Motions of the Sun and Moon, because of its gravitating towards them, in proportion to their Magnitudes and Distances. *Clarke's Rohault*, Vol. II. p. 97. See likewise the Notes to *Conversat.* 8. Vol. I.

nues fastened to another, and under another; and yet it falls, when the Air, which flows between the two, thrusts it downwards. We do not see Bodies fall down, but only in Circumstances in which we have ground to believe that they are precipitated by the Impression of some superiour Matter.

No doubt Planets ponderate; for in a word, since notwithstanding their effort to remove from the Center of their rapid Revolution, they are always in the same Orbits, a real force must stay their effort, and repel them toward the Center of their Sphere. But it seems no less true, that they are carried in a vast Fluid; and this Fluid is probably the immediate Cause of their Gravity.

Yes, the Planets float in liquid Matter, diffused every where through the Heavens. At least, one sensible Reason convinces me of it; here it is. If the Planets, Comets, and Stars, in whatever part of the Heavens they happen to be, are always visible to the whole Hemisphere of the Earth, and the Rays which make them to be seen are really material, so many Lines or Threads of Matter extended from the Stars to our Eyes; certainly the spaces in which the Planets have their Orbits, the spaces from which so long ago Comets have sent forth Terrour and Dread upon the Earth; yea farther, the Regions in which we see Stars sparkling, far from being Nothings of

of an enormous size, are filled with an immense Liquid.

But, 1. In whatever part the Planets, Comets and Stars are, we may see them from a whole Hemisphere; in order to be persuaded of this, we need only turn our Eyes toward the Heavens. 2. Luminous Rays are so many Lines, Threads of Matter. In short, they cause some change in the Organs of the Eyes; they agitate them, and sometimes wound them: therefore they touch them. Now it is only Body which externally touches Bodies; and every Body is material. 3. The Matter of the Rays ought to be extended from the Luminaries to us. For it transmits to our Senses the Impression which proceeds from the Luminaries; the Impression cannot come from such a distance but by Communication, which is successively made to the Corpuscles that compose the Rays; the Communication is made by a Stroke; a Stroke requires the Presence of Corpuscles, which strike one another. Therefore the Heavens are not void of Matter; and ethereal Matter ought to re-assume, or rather remain in possession of the celestial Regions, which it has possessed from the Creation of the World.

Eudox. But ought not this celestial Matter to make every thing languish in the Heavens, and soon stop even the Course of the Luminaries, which would meet with Resistance in it?

Arist. The Water of a rapid River* neither stops a Shallop, nor makes it flag, when it follows the Current of the Water. Why should the Matter of the Heavens, this Matter so fine, so smooth in its Surface, so easy to be divided, so quickly stop the Luminaries, which followed its course in their Revolutions.

Eudox. You are determined, *Aristus*, not to part with your Vortices? The Idea of Vortices pleases you?

Arist. I think there must be some Vortices at least round the Sun, *Jupiter* and *Saturn*, as we have observed in one of our Conversations^a, or we must renounce the Hypothesis which makes the Light to come from the Stars to our Eyes, by the Motion of etherial Matter, in order to discover to us the Revolutions of *Mercury* and *Venus* round the Sun; and those of the Satellites round *Jupiter* and *Saturn*.

Eudox. Accordingly Sir *Isaac Newton* rejected this Hypothesis^b.

Arist. Well! How then shall the Impressions of Light come to us from the Luminaries?

Eudox. Corpuscles that issue from the Luminaries themselves^c, and come all at once to us through enormous spaces, will convey those Impressions in a few moments.

Arist.

* From what has been said in Conversat. XV. p. it is evident that the Planets are not carried along in Vortexes of Matter as in a River.

^a 15 Convers. Vol. 3.

^b See Notes, p. 50. Vol. 1.

^c See Convers. 22. Vol. 2.

Arist. But, 1. In what place do not the Sun or Stars make themselves to be seen at the same time? And how can every one of those Luminaries afford a sufficient quantity of luminous Particles, in order to convey the Light themselves into almost all the Corners of the Universe? In vain would the Sun be exhaled into Corpuscles; he would not be sufficient for it, he who is but a Point in comparison of the Universe illuminated by his Light. 2. This would probably be but a small Matter for such luminous Corpuscles, to make four or five hundred millions of Leagues in the space of some few Minutes. 3. If the Particles of Bodies come so freely, and so rapidly to us, why may not celestial Bodies themselves approach a little nearer to us, in an Hypothesis in which no external Obstacle stops them?

Eudox. A secret Virtue, *Aristus*, I know not what attractive Force, attracts the Light into the Eyes with an inconceivable quickness.

Arist. This secret Virtue, *Eudoxus*, this attractive Force has something in it, which seems a little mysterious, and too sublime for us. Pray, do you explain it.

Eudox. According to the * Principles of Sir *Isaac Newton*, a general Attraction reigns in the

* These Principles I consider, says Sir *Isaac*, not as occult Qualities, supposed to result from the specifick Forms of Things, but as general Laws of Nature by which the Things themselves are formed; their Truth appearing to us by Phenomena, though their Causes be not yet discovered. For these are manifest Qualities,

the Universe. This Attraction is Gravity ; and the Cause of it is unknown. Gravity or Attraction gives certain Bodies a Tendency, which carries them toward one another ^d, whilst a contrary Virtue, but equally incomprehensible, separates certain Bodies from one another ^e. Hence the regular Motions of Planets ; a Gravity, a constant Attraction retains them in their Orbits in the Vacuity itself. Why is the Light spread over Bodies ? I know not what Virtue attracts it over them. A Ball plunged into Water, ascends again whenever it is at liberty ; because the Earth attracts the Water more strongly ^f. Whence
is

lities, and their Causes only are occult. And the *Aristotelians* gave the Name of occult Qualities not to manifest Qualities, but to such Qualities only as they supposed to lie hid in Bodies, and to be the unknown Causes of manifest Effects: such as would be the Causes of Gravity, and of magnetick and electrick Attractions, and of Fermentations, if we should suppose that these Forces or Actions arose from Qualities unknown to us, and incapable of being discovered and made manifest. Such occult Qualities put a stop to the improvement of natural Philosophy, and therefore of late years have been rejected. To tell us that every Species of Things is endowed with an occult specifick Quality, by which it acts and produces manifest Effects, is to tell us nothing ; but to derive two or three general Principles of Motion from Phenomena, and afterwards to tell us how the Properties and Actions of all corporeal Things follow from those manifest Principles, would be a very great Step in Philosophy, though the Causes of those Principles were not yet discovered: And therefore I scruple not to propose the Principles of Motion abovementioned, *viz.* Gravity, and that active Principle, which causes Fermentation and the Cohesion of Bodies ; they being of very general Extent, and leave their Causes to be found out. *Opticks*, p. 337.

From hence it appears, that our Jesuit has either wilfully or ignorantly perverted the Meaning of this Great Man.

^d See Notes, p. 119, & p. 177. Vol. 1.

^e Ibid.

^f Ibid.

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is it that Salt of Tartar is dissolved *per deliquium*? The Vapours, which flutter in the Air, being attracted by this Salt, shake, break, and dissolve its Particles. If Aqua-fortis dissolves Silver, without changing Gold; if Aqua-regia dissolves Gold, without changing Silver; this is not because the Particles both of the one and other Menstruum, are not fine enough to penetrate equally into the Interstices of the Silver and Gold: but a secret Virtue attracts all the Violence of the Aqua-fortis into the Interstices, and upon the Particles of the Silver, whilst an opposite Force repels the Action of Aqua-regia; a secret Virtue attracts the whole Violence of Aqua-regia into the Pores, and upon the Particles of Gold, whilst an opposite Force repels the Action of the Aqua-fortis^s. Attraction produces all chymical Miracles, all Fermentations, all subterranean Fires, all the Fires in the Heavens, all Lightnings, all Thunders, and all the burning Heat of the Sun. The roundness of a drop of Water, of a drop of *Mercury*, of the Earth itself, proceeds from the same Principle. From this unknown Principle results the Beauty of the Universe^h. Many Persons of Judgment have gone into this Principle; and it daily gains new Partisans in Countrys where Philosophy is in esteem.

Arist. Certainly, *Eudoxus*, that Naturalist, who brought this Principle into repute; must have

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^s See Notes Conversat. 3. Vol. 2.

^h See Notes Vol. 1. p. 119.

have been as great a Philosopher as he was, to call back with so much success those occult Qualities, those active Virtues, which arise from the particular Nature of each Species, those specifical Virtues of Bodies; those I know not whats, which for the space of many Ages have produc'd the finest Phænomena of Nature.

Eudox. But he roundly declares, that he does not acknowledge those Qualities¹.

Arist. But Attractions, whose Cause we are perfectly ignorant of, which excite no Idea in the Mind; and which nevertheless make up the Harmony of the Universe, are they not equivalent to occult Qualities? These Attractions have not their Principle in Impulsion, since they make them reign even in a Vacuum. They do not refer them to the immediate Will of God*, which produces no change in Bodies that surround us; but in the moment that it is determined by Percussion. We must then conjecture Possibilities out of sight, and throw ourselves into Darkness on set purpose, or ascribe Attractions to the Nature itself of Bodies; and if this is not to call back, in spite of one's self, the Qualities proscrib'd in several Places, it is at least something very like it.

Eudox. To assign such Qualities for Causes to the Effects of Nature, would be to say nothing.

Arist. To assign attractive Virtues, of which one knows neither the Nature nor the Cause,
for

¹ See Notes Vol. I. p. 120.

* See Notes p. 304. *supra*.

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for the immediate Principles of those Effects, is this to say much more?

Eudox. To acknowledge Gravity, and the Cause of Fermentation, that is, attractive Virtues, for the fertile Principles of Motion, although one be ignorant of the Cause of those Principles, would not this be to have made great Progress in Physicks? Thus Sir *Isaac Newton* proposes those Principles, as Principles of Motion.

Arist. Was it ever doubted, that Gravity and the Cause of Fermentations, were fertile Principles of Motion? If I am not mistaken, to acknowledge that those Principles of Motion consist in Motion itself, and in Impulsion, would be to have made greater Progress; and I believe that this is a Progress, which has been made. For in a word, as we have remarked more than once, a Body is but a small Portion of Matter; naturally it is only a Substance impenetrable, more or less long, large, deep, modified, and figured. In this there is no Bias, no Efficacy; a perfect Indifferency to Motion or Rest, to such or such a Direction. Therefore a Body must receive Motion and Direction from some foreign Cause. Is this Cause the Will of Man? We may will as we please; inanimate Bodies neither move, nor change their Direction, without the Stroke or Rencounter of another Body. Is it precisely the Will of God? No, The Author of Nature does not move
the

the Bodies which surround us, nor change their Direction, unless the Stroke or Rencontre of another Body determine him. You do not see a Stone move without Impulsion toward the East or toward the West, toward the North or toward the South; and we never see a Body change its Condition, nor Direction, but when we have ground to believe that Percussion has a share in the Change. Iron moves as of itself to adhere to the Loadstone; but we know that some imperceptible Matter comes out of the Pole of the Loadstone, which enters again through the other Pole in form of a Vortex; since we see the Vortex describ'd at once upon Filings of Steel; this Vortex attaches the Iron to the Loadstone, or drives from between the Iron and the Loadstone, the fine Matter or Air whose Elasticity or precipitated Return thrusts the Iron toward the Loadstone. Therefore Gravity, which carries Bodies towards a common Center, and Fermentation which agitates them universally, have their immediate Principle in Motion and Impulsion.

If Gravity carries sensible Bodies towards a Center, an imperceptible Matter strikes and directs them. Why does Milk, which boils, swell by a sort of Fermentation? The Corpuscles of Fire, lighter than the surrounding Air, and thrust upward, penetrate the Pores of the Vessel, are rapidly darted into the Interstices of the Liquid, and enlarge them so
much

much the more, because they dilate the internal Air; the Interstices being enlarged, the Milk presents to our Eyes a larger Bulk: this is a sort of Fermentation, whereof Impulsion is the nearest Cause, and which does not seem to proceed from an attractive Force, whose Principle is so deep a Mystery. The Cause of other Fermentations is a Cause much like the same, according to what we said when we had a Conversation upon Fermentations^k. The Action of a subtile Matter always violently agitated, and the Springs of the internal Air, set at liberty in the mixture of Liquors, disorder and dissipate their Particles, and are the physical Principles of Fermentations.

Eudox. After all, *Aristus*, suppose we should make the magnetick Virtue a little more general; suppose we should extend a little farther, than what is ordinarily done, this Virtue of attracting, which is observed in *Spanish Wax*, in *Amber*, and in the *Loadstone*, would this be clashing with Philosophy?

Arist. No: Two adjacent drops of Water, or two drops of Vinegar, &c. are easily united, so as to make only one drop, that we may conjecture some Species of magnetic Virtue to be in them. But I perceive in that, as in the Union of Iron and the Loadstone, some impulsion. If, for example, some fine Matter issues out of a drop of Water, which
finds

finds an easier access into another drop of Water than into the Air, the fine Matter passing with united forces from one drop into another, will drive out the Air from between the two, and take away the Equilibrium; and the external Air, which will push them, will at once re-unite both in one. But they will have Tendencies and Attractions without Impulse, without Percussion; since they will have the Planets to attract one another, without letting go their hold, in Vacuities almost infinite; and this is what is no more probable upon your Principles, *Eudoxus*, than mine.

Eudox. Formerly, *Aristus*, you jested upon subtile Matter¹, and to-day you take upon you the Defence of it in good earnest, and diffuse it every where.

Arist. This Matter, however minute it may be, seems to me to be too serviceable to those very Persons who disown it, for me not to interest myself in its behalf. If they do not receive it from the hand of M. *Descartes*, I wish they would condescend to receive it from the hand of *Aristotle*. This ancient Philosopher made use of it to fill up all the Interstices of Bodies, since he allowed no Vacuum in the Universe. Thus beside the Fire, Air, Water and Earth, he acknowledged a fifth Species of Matter diffused every where, which he called the *Æther*. Is not this the subtile Matter?

Eudox.

¹ 5 Convers. Vol. I.

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Eudox. But this fine Matter, which overflows the Universe, whence has it its Motion *, its Force ?

Arist. From God ; for to conclude, there must be a first Cause of Motion ?

Eudox. On the first opportunity, *Aristus*, let us make God himself the Subject of a Conversation. Let us endeavour to ascend by created Beings, as by steps, to the Creator. This is the end of Philosophy. God was the beginning of our Conversations, let him also be the end of them.

* If Gravity depended upon any known Law of Motion, it ought to be referred to a stroke from an extraneous Body ; and because Gravity is continual, a continual Stroke would be required.

If there be such a sort of Matter continually striking against Bodies, it must of necessity be fluid and very subtile, so as to penetrate all Bodies ; for Bodies that are any how shut up in others, are heavy.

Now let a Mathematician consider, whether a Fluid so subtile, as freely to penetrate the Pores of all Bodies, and so rare, as not sensibly to hinder the Motion of Bodies, (for in a Place void of Air, the Motion of a Pendulum will be continued very long) can impel vast Bodies towards one another with so much force ? Let him explain how this Force encreases in a Ratio of the Mass of the Body towards which another is carried.

Lastly, Let him shew, what seems most difficult to me, how all Bodies, in any Situation whatsoever (if the Distance, and the Body towards which the Gravitation is, remain the same) are carried with the same Velocity ; that is, how a Liquid which can only act on the Surfaces, either of the Bodies themselves, or their internal Particles, to which it is not hindred from coming by the Interposition of other Particles, can communicate such a Quantity of Motion to Bodies, which in all Bodies exactly follows the Proportion of the Quantity of Matter in them ; which is proved to obtain every where in Gravity.

Yet we do not say, that Gravity does not depend upon any Stroke, but that it does not follow from that Stroke, according to any Laws known to us. *s'Gravesande's Phys. Elem. Vol. II. p. 215.*



CONVERSATION XXII.

*Upon the Existence of GOD.**Arist.*

OFTEN, *Eudoxus*, have you made me observe in Nature, Characters of a Wisdom wholly divine. I always considered them with new pleasure; and should be overjoyed if you would bring them to my remembrance, and make me to see with the Eye, if possible, by what steps you ascend as a Philosopher, even to God himself.

Eudox. 1. I have a Body, this I can't doubt of. My Body has received Being from a great number of Bodies, successively born of one another. I see the same Succession both in Plants and Animals, in all Species of organized Bodies.

2. If all these successive and organized Bodies are of themselves only possible, if their Nature or Essence is not Being itself; there must be, without the Assemblage of those Bodies, a necessary Being, from whom every Species has received its Existence. If every
thing

thing were possible only of itself, no Species of Body would exist; for no Species of Body would have a Principle or Source of Being neither in itself, since of itself it would only be possible, and what has not Being, cannot give it; nor in any other actual Being, since every other thing being of itself only possible, would have no efficacy; nor in Non-entity, since Non-entity, which is nothing, and which contains nothing, produces nothing. But all successive and organized Bodies are of themselves only possible; none of them had Being in its Essence. We see them all succeed one another, change, and disappear. Therefore without the Collection of those Bodies there is a necessary Being, from whom every Species has derived actual Being.

3. This necessary Being is an intelligent Being. The Art, which manifests itself in the Structure of Bodies, which owe their Being to him, is the Seal of Intelligence. Who put this Heart into my Breast^a, which dilates itself to receive the Blood, and is alternately contracted, in order to throw it with violence into an Artery, which is divided into thousands of imperceptible Branches, in order to convey Blood, Nourishment, and Life into all the parts of my Body? Who placed the Veins above the Arteries, in order to carry back and perfect the Remainders of Blood in the Focus of the Heart? Who disposed those Valves in
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the Arteries, those Species of Suckers, which permit the Blood to flow from the Heart or Center to the Extremities, opposing its return ^b? Who had skill, on the other hand, to insert into the Veins those Valves, those Suckers, which permit the Remainders of Blood to return toward the Heart, to be purified there, without allowing it to flow back toward the Extremities? Whence come those Passages, those Valves situated a contrary way, those Vents so well disposed in the right Ventricle of the Heart, which direct the Blood through the Branches of the pulmonary Artery, into the Lungs to be cooled, thereby receiving the Air, which Respiration brings thither thro' the Trachea? The Mechanism of the left Ventricle of the Heart is no less ingenious, nor less happy for receiving the cooled Blood, and continuing the Circulation, which distributes the Aliments. But the Blood is consumed by Nutrition and Transpiration. The Business is to repair it by new Nourishment*. I need only will it. The Spirits flow in the Nerves; the Muscles are inflated, fall again, are lengthened and shrink; the Teeth being solid and sharp, break the new Nourishment: The Epiglottis, like a Sucker, or a Draw-bridge, lowers itself to let the comminuted Nourishment descend into the Stomach, without hurting the Trachea. The
Stomach

^b 8 Convers. Vol. 2.

* 9 Convers. Vol. 2.

Stomach incides them with its Acids, and digests them. The best digested Juice is fine enough to be filtred through a thousand Interstices. The Pressure makes it pass from the Interstices into the lacteal Veins, thence into the Channel, which carries it, by the help of certain Valves, into the Veins, which convey it into the Heart to be purified there by Fermentation. By virtue of fermenting and circulating with the Blood, it takes the Nature of Blood itself, in order to cherish Life universally, to temper and mix those Colours, which spread over the Countenance a lively Complexion, and make a Carnation which Art can never imitate but imperfectly. How well is this Mechanism contrived!

But how do I see at once the Sea, the Earth, and the azure Heavens bespangled with a million of luminous Stars? How do so many immense Objects come to be ranged in so small an Organ *? The Eye, in which a celestial Flame shines, is round. Its Surface receives Rays from a greater number of distant Places. Those Rays, broken by the different Texture and Figure of the Humours of the Eye, continue to approach one another, till the Rays parted from every Point of the Objects, are united upon the Retina, and convey thither the Impressions which they have received †. Hence, the Impressions, the faithful

* 20 Convers. Vol. 2.

† 15 Convers. Vol. 3.

faithful Images of Objects, from the Sun even to Atoms, pass through the Fibres of the optic Nerve into my Brain, in which whatever is most wonderful in the Universe, seems united on a sudden.

But how is it that I find, even when my Eyes are shut, all the Images I please in my Brain to the degree mentioned above? I call them, and immediately they present themselves. I disperse them, and they disappear*. I need only will it, and forthwith they return. Is this a Cabinet of Paintings, whose Pictures are ready of themselves to be ranged at my pleasure? The Changes which are made in the Substance of my Brain, are new Images, more resembling, a thousand and a thousand times better finish'd than the Master-pieces of *Rubens*, *Titian*, or *Zeuxes*. Whence arise those Textures of Particles in this soft Substance, in this Species of Clay, so docile both to the Impressions of the Objects which strike my Senses, and also to the Desires of my Will?

This marvellous Art, this Design so well concerted, which I observe in my Heart, Arteries, Veins, the Motion of my Blood, the Organs of my Senses, my Eyes, and Brain; I also remark it in all the parts of my Body. It is manifest, as we have already seen, in the Animals which are millions of times smaller
than

* Demonstration de l'Existence de Dieu, proportionnée à la faible intelligence des plus Simples.

than a Mite, than the lowest perceptible Insect. This Art, this Design, is above the reach of all Men, even the most knowing, though all their Wits were united together, to invent, comprehend, or to imitate.

Could the first Being, the necessary Being, who formed the different Species of Animals, make so much Art to shine universally without Understanding? Could an irrational and blind Being have a thousand and a thousand times more Judgment, Wisdom, and Skill than all Mankind together?

But what could not Chance make, that obscure Abyss, in which some will have the Mind to be lost? Or shall we rather say, what could it make regular? Chance is only a little Matter agitated, which always tends to move in a right Line, irrational and blind. Is it surprizing, that for the space of six thousand Years it has made, at most, but some deformed Caverns, not one mean Insect, that we know of, nor one Blade of Grass? If I suspected a Watch to be the Workmanship of Chance, I should pass for a Fool equally, and with reason, in the Judgment of a wise Man, and in the Judgment of an incredulous Person. What would it be, if the Watch should wind up itself, as my Body renews itself; if the Watch were as docile and as submissive to my Will, as my Body; if the Watch folded up itself, defended itself, and run away like the Body of an Animal, to

preserve itself; if the Watch produced itself a-new in other Watches? To honour Chance with the Mechanism of an organized Body, is designedly to prefer Darkness to Light, acknowledged at the bottom by a Sceptick, as well as a Philosopher.

If a Man, if a Philosopher should take it into his head to say, upon seeing *Versailles*:
“How foolish are Men! They imagine that
“it requires some well-skill’d Architect to
“build the finest Palace. But this Palace so
“much boasted of, how was it reared? The
“Stones agitated by I know not what fortuitous Motions, without the Action of any
“Intelligence, did issue out of the bosom of
“the Earth. They were hewn out of themselves, by encountering one another; they
“were thrown and ranged above one another. The Marble imitated them. The
“Stones and Marble had skill of themselves
“to form those Rooms, those Galleries, those
“Halls, this Edifice which surprizes all Nations. The Wainscoat, the Gilding, the
“Cieling, the Paintings so finish’d, which
“have so much Grace, Majesty, and Life,
“those Glasses in which one sees one’s self
“produc’d again on all sides, those delicious
“Gardens, those Fountains which rise to the
“Clouds, those Pictures which seem to think,
“and those Statues which seem to talk;
“all this is only the Game of Chance.” No Man would be so simple, no sound Mind
would

would be so fantastick as not to judge the pretended Philosopher worthy of a Mad-house. In vain he might say: "But after all, I do not clearly see the Impossibility of what I advance." That is not at all astonishing, might we answer him, (if however we would vouchsafe to make him any Answer) since you do not see that it is even Madness itself which dictates what you advance.

Now there is infinitely more Art in an animated Body, in the vilest Insect, than in the most curious Watch, or the most admirable Palace. Men are capable of inventing this Watch, and of raising this Edifice; but they can invent nothing, execute nothing which approaches an animated Body, even the vilest Insect.

To conclude, could Chance, or I know not what Collection of agitated Matter, give us Veins for containing the Blood, a Heart for receiving, perfecting, and diffusing it; Nerves and Muscles for the Motions of the Body, Spirits for the Mechanism of the Nerves and Muscles*, Lungs for Respiration, Feet for walking, a Palate for tasting, a Nose for smelling, Eyes for seeing, Ears for hearing, a Voice for communicating our Sentiments, and for enjoying what is most agreeable in Life, the Conversation of Men, and of our Friends? Designs thus executed, are not the Productions of blind Matter, of

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* Vol. 2. Conversat. 8 & 9.

a fortuitous Motion. Therefore it is evident that the necessary Being, who gives Existence to the different Species of Animals, is an intelligent Being.

4. This necessary and intelligent Being is not at all Matter; Matter and this intelligent Being are two Substances, two Beings really distinct. This intelligent Being thinks; forms the best contrived Designs, and executes them. Matter does not think at all. If Matter did think, which in its natural State is only Extension, Extension would think; whereas Extension has no Thought. Otherwise, Thinking would be a manner of Being, a Modification of Extension, and consequently a Thought would be a modified Extension. Now Thought is not Extension. Extension is divisible, coloured and figured. But in vain should I attempt to divide a Thought. Judgment, whether affirmative or negative, has no parts which one can divide; Love has none. I may do what I please, I cannot form a fourth, a half, nor three fourths of a Judgment or Act of Love. It is a Testimony of my Conscience itself, which assures me of it, an internal Sentiment which cannot deceive me. Pray, what Colour does one perceive in Love, or in Hatred? What Figures have our Judgments, our Passions? Are they Triangles or Squares? Therefore Matter does not think at all.

Every

Every part of Matter join'd to another, makes a Figure; but I may vary my Thoughts as I please, and match them differently, I always perceive the Changes of my Sentiments, but never their Figure.

Matter is naturally susceptible only of Rest, Motion and Figure. And neither Figure, nor Motion, nor Rest, are Thought. My Body passes from Rest to Motion, from Motion to Rest, and assumes a new Figure, without any vicissitude of Thoughts. If the Changes of my Body were so many new Thoughts, I should be sensible of them. We are admonish'd by internal Sensation concerning whatever passes in our Thoughts.

Probably the Food, which we take, thinks not at all. Should it begin to think after it has past into the Substance of our Bodies, where all is dissipated and renewed by an imperceptible Transpiration, and by a continual Succession of Nourishment? Our Thoughts would be exhaled by Transpiration. The same Thoughts however are found again in us, whenever we have a mind; we need only will, and the Thoughts of Infancy itself return, and present themselves to us.

Finally, the finest and most agitated Atom cannot be in an instant both in the bosom of the Earth, and also in the highest part of the Heavens; it is not every where at the same time. My Thought in a moment penetrates the Heavens and the Earth; my Thought

is in a thousand and thousand Countrys at a time. In the twinkling of an Eye it embraces the most extended and most universal Object. I will it; and already it has run over the whole Universe.

Therefore the necessary and intelligent Being, and Matter, must be two Substances really distinct. In a word, the necessary Being, who gives being to different Species of Animals, is a Spirit. This is precisely what the *Epicurean* and *Spinozist* would not acknowledge, if they could.

5. What difference between this Spirit, and the Spirit which thinks in me! That knows perfectly the Mechanism of Bodies. It had skill to form, and plentifully to spread over the Surface of the Earth, innumerable Species of Plants and Animals, in which my Spirit incessantly discovers new wonders, which it scarcely knows how to admire, and which it can neither imitate nor comprehend*.

6. A Spirit, who knows how to make so wonderful an use of Motion, ought to be himself, I think, the first Mover, if the first Principle of Motion is external to Matter. For in a word, this Principle must be a Substance different from Matter, or Motion must be essential to Matter, or Matter must give itself Motion. Matter does not move essentially. In its natural Condition, it has nothing

* Convers. 6. Vol. 3.

thing but Extension. The Idea which represents it to us, founded upon Experience, offers no other thing to our Minds. And it is evident, that Extension may subsist without Motion. The Mind discovers in it nothing but a perfect Indifferency to Motion or Rest. Thus we see the same Body sometimes in Rest, sometimes in Motion. By the same reason, Matter does not move itself, since it is in a perfect Indifference, without force, without bias, and without efficacy. Hence a thousand sensible Bodies remain whole Ages in the same Place, until some foreign force come to displace them. Therefore Motion, which seems to animate inanimate Bodies, Luminaries, the Heavens, the Universe, proceeds from a Principle external to Matter. Therefore the Spirit, necessary and superiour to all human Intelligence, is the first Mover.

7. This Spirit, the first Mover, is not a Soul substantially united to Matter, and which alone, as the *Pythagoreans* imagined, animates the Universe, and all the Bodies which compose it. This Soul must necessarily have a thousand Qualities strangely opposite in different Bodies, without knowing it. It would be at the same time ignorant and wise, dark and enlightned, full of Contempt for what it esteemed, of Love for what it hated, peaceable and furious, a Friend and Enemy of Laws, pious and impious, virtuous without virtue, free without liberty, happy and unhappy.

How

How could a knowing, wise, and simple Spirit, who cannot be ignorant of what passes within itself, contain so many Varieties, Caprices, and Contradictions, without its knowledge ?

8. Notwithstanding the Spirit, the first Mover, who regulates and directs the Motions of the Universe, possesses Immensity ; his Action makes itself felt throughout the whole Universe. This Spirit is independent, since he derives his Being from his Essence itself. He is eternal ; what cannot but exist, can neither begin, nor cease to be.

9. The independent, eternal Spirit has no need of external and sensible Beings, whose Structure and Motion constitute the Beauty of the Universe, since having produc'd them, he contains them eminently in himself. Therefore he has produc'd and does preserve them freely ; he is free. And since the Production and Preservation of the visible World depend upon his Will, Wisdom, and Power, he must be the Master and Ruler of the Universe ; the Sovereign of Heaven and Earth. Therefore there is a necessary Spirit, distinct from the Universe, the Author and Sovereign of the Universe. These are, *Aristus*, some of the Steps by which my Mind ascends even to God himself.

10. In order to reach thither still more swiftly, nothing more is required than a single Glance of the Eye. This excessive plenty
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of Stars *, those pure Fires, do not sparkle in the dark Azure, but to discover to us the hand of God in all his Works. Night proclaims it to Day, and Day to Night. I perceive Characters of his Simplicity even in the diversity of Plants, Flowers, Fruits, Animals, Faces, Sounds and Colours^c. I see Characters of an unchangeable Being in the regular vicissitudes of the Seasons; his Liberality in the Treasures of the Earth; his Providence in those extended Plains covered with rich Harvests; his Greatness in those Abysses of Air and Water, in this immense Vault of the Heavens. We every where see his Wisdom shine, which forms the Light to illuminate us; the Air, for Respiration; the Heat, for cherishing the Principle of Life which we bear in ourselves; the Plants, to furnish us with wholesome Food, and Remedies for Diseases; the Bees, to act with an Order which may serve us for a pattern^d; the Sea, to be the Center of Commerce; the Clouds, which fly as upon the wings of the Wind to water the Fields; the Sun, to enlighten, render fruitful, and animate all by his beneficent Aspects; the Moon and Planets^e, to remit to us at least some Rays, when the Sun goes to minister elsewhere; the Day, for being the time of Labour;

* 14 Convers. Vol. 3.

^c Convers. 1, 2, 3, 4, 5, 6. Vol. 3. Convers. 13, 22, 23, 24. Vol. 2.

^d 6 Convers. Vol. 3.

^e 12 & 13 Convers. Vol. 3.

Labour; the Night, to encompass the Earth with its Shades, to spread Silence thereon, to refresh the Body, and to recruit the Spirits; the Morning, to bring back the Day, to call Man again to labour, to revive the pleasures of Society, and to re-animate Nature.

11. But why need I run through so many pieces of Workmanship that have come out of the hands of God, that I may still discover new Perfections in him? Perfection itself, Being is his Essence, his Nature*. He is independent;

* *God governs all things, not as a Soul of the World, but as the Lord of the Universe.——God, is a relative word, carrying in it the Notion of Relation to Servants. And the Godhead of God is His Dominion: A Dominion, not like that of a Soul over its own Body, but that of a Lord over his Servants.——God is Eternal and Infinite, Omnipotent, and Omniscient: That is, he endures from Everlasting to Everlasting, and is present from Infinity to Infinity: He governs all things which are, and knows all things which are possible to be known. He is not Eternity or Infinity, but Eternal and Infinite. He is not Duration or Space; but He endures, and is present. He endures always, and is present every where; and, by existing always, and every where, constitutes Duration and Space; Eternity and Infinity. Seeing every Particle of Space is always, and every indivisible moment of Duration is every where; surely it cannot be said of the Maker and Lord of all things, that He is [at no Time, and in no Place] never and no-where. He is Omnipresent, not only virtually, but substantially: For Power cannot subsist without a Substance. In Him all things subsist and move, but without a mutual affecting each other, [such as is between Soul and Body] God is no way affected by the Motions of Bodies; and the Motion of Bodies meets with no Obstruction from the Omnipresence of God——He is altogether without Body or Bodily Shape; and therefore can neither be seen, nor heard, nor felt, nor ought to be worshipped under the similitude of any corporeal Thing. We have Ideas of His Attributes; but what the Substance of any Thing is, we know not at all.——The very Substances themselves, even of Bodies, we cannot come at the Knowledge of, either by any of our Senses, or by any reflex Act of the Mind: much less have we any Idea of the Substance of God. Him we know, only by His*
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dependent; nothing external can limit him; there are no reasons for attributing to him one Perfection rather than another. Could he be limited by himself? Could his Nature require Bounds? But Perfection, but Being needs no Bounds; this would be to tend to his own Destruction, to Non-entity, since Bounds are a Negation, Non-entity itself. Therefore a necessary, independent, eternal Spirit, God, in one word, possesses fulness of Being, of Perfection. Now all possible Perfections, Knowledge, Justice, Liberry, Power, &c. are so many degrees of Being: Therefore God contains all possible Perfections: Therefore he is infinite, and is an infinitely perfect Spirit.

12. It is evident, that Matter is not an infinitely perfect Being, no more than our Spirits, whose Bounds we are sensible of. It is divisible; Division takes away from it the Perfection which it had. It cannot give itself Motion; it must borrow it from some foreign Cause; it loses it without possibility of producing it again. It does not think; it is blind, irrational, as we have observed. Therefore it is not a necessary Being; therefore of itself it is only possible; therefore it has received Being as well as Motion; therefore

Properties and Attributes, and by His most Wise and Excellent Disposition of Things, and by final Causes: and we adore and worship Him, upon account of His Dominion. For a God without Dominion, without Providence, and final Causes, is nothing but Fate and Nature. Newton's Princip. Schol. General.

fore Reason in concert with Faith, teaches us that there is a Spirit really distinct from the Universe; a Spirit, the Creator of Heaven and Earth; a Spirit who formed out of Nothing both Heaven and Earth: and this is the God whom my Mind acknowledges, and my Heart adores.

Arist. Do you comprehend, *Eudoxus*, how the *Spinosist* can take upon him to advance, that he discerns only one Substance; that this one Substance has two essential Properties, namely Extension and Thought; and that the different Beings, which compose the Universe, are only Modifications of those two Attributes, which succeed one another by an eternal and necessary Concatenation?

Eudox. That is clashing with Reason, 'tis true, since Spirit and Matter are Substances evidently distinct; it is rashly to confound the Worker with the Work; it is to annihilate the Creator, to substitute the Creature in his stead. But when Passion, Extravagance, and Impiety have taken possession of the Mind and Heart, what Monster is not one capable of bringing forth? *Spinosas*, born in the last Age, but born and educated in Judaism, carried the Blindness and Hardness of it much farther than his Fathers. He abjur'd their Faith; but this was only in attempting to destroy that God whom they worshipped from the Birth of the World. And how dares he attack him? By Reasonings that proceeded
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from his Heart rather than his Judgment. He begins with laying down this for a Principle, That whatever exists, and is conceived alone, without the Idea of another Being ^f, is a Substance. So far his Judgment is sound. But then he immediately concludes, that there never was but one Substance. It is his Heart alone which concludes after this manner: *The Fool said in his Heart*, Dixit insipiens in corde suo ^g. For in short, thus, I think, a sound Judgment would reason: Whatever exists, and is conceived alone, without the Idea of another Being, is a Substance. This Principle is indisputable. But every one may know by the Testimony of his Senses, and by an internal and infallible Sentiment, that there is a great number of things, which are conceived alone, without the Idea of another Being; such are a Circle, a Rose, a Diamond, a Man, &c. Therefore it evidently follows from *Spinoza's* Principle, that there are in the Universe several Substances; and the first Attempt which he makes to drain the Source of Truth, throws him into an unpardonable Contradiction. But how should one attack the Principle itself of Reason by judicious Reasonings?

Does *Spinoza* reason better, when he pretends that his Substance has two essential Properties, Extension and Thought? No indeed.

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^f Ethics, pars 1. p. 1. & 6.

^g Pf. 52.

Two essential Properties of one and the same Substance arise from the Nature of the Substance; they are not really distinct, they are the Substance it self. The Properties of a Triangle do not differ from the Triangle; the one is really the other, they are the Triangle itself. This being granted; if Extension and Thought are the essential Properties of one and the same Substance, of an individual Substance, they are really the same thing. Therefore Extension must think. But as we have observed, Extension does not think: if Extension thought, a Thought would be a modified Extension; whereas Thought is no Extension. Extension is divisible, figured and coloured; but in vain should I attempt to divide a Thought, a Judgment, an Act of Love. Love has neither Colour nor Shape. An internal Perception, which is not liable to Delusion, and does not suffer us to doubt of it. Therefore Thought is not Extension. Truly, if we could suspect that Stone and Iron think, the Sympathy of the Loadstone and Iron would in that case be a real Passion. But then we must say a piece of Thought, as they say a piece of Stone, or of Iron, and extinguish all the Light which we receive from our Senses or Reason. Therefore the single imaginary Substance of *Spinoza* cannot have two Properties, whereof the one is Thought, and the other Extension. Therefore the great Principle of the most famous among the modern

Atheists

Atheists has nothing in it but what is frail, and much better demonstrates the Perverseness of his Heart, than the Strength of his Judgment.

I question, *Aristus*, whether you will find him more reasonable, when he imagines the Universe to be the Result of the Modifications of two incompatible Attributes, to be a Concatenation of necessary Productions, in which only a natural and incomprehensible Necessity bears sway, and when he gives to this imaginary Concatenation, to this sensible Universe, the Name of an infinitely perfect Being.

Arist. 1. The Universe cannot be the necessary effect of the Modifications of two chimerical Attributes.

2. Man is free; an inward and real Perception convinces us of it. Why cannot we doubt of the Existence of Thought? Because we are conscious of it. We are equally conscious of Liberty. Liberty makes all Men conscious of it: therefore all Men are free. Thus the persuasion of it is general. It is one of those first Truths engraven deeply on the Soul, and which it is in vain for one to attempt to wear out. But how could Liberty subsist, where only a natural Necessity prevail'd?

3. The Universe is divisible, subject to a thousand Changes, to a thousand Vicissitudes; Ignorance, Vice, and Disorder, reign therein amongst Men in a thousand Places; there the Brother pollutes himself with the Blood of

his Brother; there the Son waits for the Death of his Father. How many Persons unhappy throughout their whole Lives! What do I say? In *Spinoza's* Principles, the Universe is but one Substance, it is properly only Matter, without Spirit, without Liberty; in it, one is happy and unhappy without deserving it, without knowing it. Do they think that they are speaking to Men, when they abuse Terms so far, as to prostitute to an heap of so many Imperfections the Name of an infinitely perfect Being, which Reason hath always consecrated to the supreme Being, to the Spirit, Creator of the Universe. They must have a strange desire to declare themselves Atheists, and to exceed the Incendiary of the Temple of *Ephesus*, in order to make themselves famous. After all, *Eudoxus*, I understand that the Heart endeavours to make Atheists, and that there are hypocritical Professors of Atheism: But do you believe that there are real Atheists among the Incredible, or among the Wits of our Days?

Eudox. A real Atheist would be a Man, who making use of his Reason, would judge, and persuade himself that there is no God ^a. But how can any one judge and persuade himself that there is none, and yet make use of his Reason? The Mechanism of the Human Body, the wonderful Union of Body and Soul,
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^a As Father *Tournemine* observed in his Reflections upon Atheism.

so many Species of Plants and Animals, the Motions and Splendour of the Luminaries, the alternate Succession of Day and Night, the Vicissitudes of the Seasons, the Order and Harmony of the Parts of the World, all declare to us, all reveal to us a Being superior to all that we see, a Spirit Creator of the Universe, a God. There is no reason for not acknowledging him. *I do not evidently see; I do not comprehend*: Here it is that all the Reasons of the Infidel terminate. As if the Weakness of our Minds ought to comprehend the whole depth of the most sublime Being, and the first of Beings; and as if Incomprehensibility ought not to be one of the Prerogatives of the supreme Being, of the Spirit who had the skill to create Man; Man, I say, who does not comprehend himself. Thus an hundred impious Persons being converted, have acknowledged, that in vain they had attempted to put out that Light which enlightned them concerning the Beginning and End of Man. Those who were not converted, have they been beyond all doubt ^b? Two or three have carried their Infatuation even into the middle of the Flames; but shall we not believe that Folly, Despair, Madness, precipitated them into it rather than a persuasion of their Judgment? If they were persuaded upon solid Reasons, they had no more to do but to dissemble a moment. And by that means they would have prolonged their

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Days;

^b Reflections upon Atheism.

Days; they would have escap'd the Violence of the Flames; they would have secured to themselves the only Good which they could expect. Far from disgracing themselves, they would have prevented the shame of dying look'd upon as Monsters of Nature, and accursed by the whole World; and in such a Persuasion, they would have seen nothing to be feared on the part of an avenging God.

Arist. What has surprized me more than once in certain Companies, and what surprizes me as much almost as those blind Transports, is the Licentiousness with which Persons, otherwise civiliz'd and ingenious, run out sometimes in speaking of what is most real and venerable. They are favoured by Fortune; they have discovered some Secrets of Nature; they know how to turn a Thought, or a Verse. This is enough; without waiting for Age, they have a right to judge sovereignly of all Things; what is the most sublime must be brought before their Tribunal. If any difficulty occur above their reach, if they do not comprehend the most elevated Mysteries, they will not impute the Fault of that to the Weakness of their Judgment; they owe no submission but to Evidence. When we do not believe them upon their Word, we are in the wrong; and whilst they see the most Wise, most Skillful, and most Learned, give up themselves to the Voice of Nature, and reverence its Author, they seem, in spite of Evidence
itself,

itself, to search out Reasons for doubting, or of infusing Doubts into the Minds of others, in order to quiet the Remorses of their Conscience by the apparent Multitude of Unbelievers. They will be credulous in the Commerce of civil Life. You would say, that Doubting seems not to be permitted them but when they attack the Foundations of Religion. Every thing presents a God to them, whom they desire never to see.

Eudox. That is as much as to say, that Talents and Benefits make Men ungrateful toward the most liberal of Benefactors. We enjoy the Light, and yet will not lift up our Eyes toward the Luminary which makes it shine upon us. Passion is afraid to see all that may mortify it. An Idea of a God of Vengeance humbles Pride, prescribes narrow Bounds to Pleasure, and condemns Injustice and Interest. Passion being mortified, would destroy the Source of its Torments; the Heart being seduced, revolts against him who holds it between his Hands; it errs, it draws over or endeavours to draw over the Judgment into its Errors, in order to withdraw itself from the importunate Idea of Punishment. It exhausts itself in Hypotheses to make Conscience silent. Conscience that cannot be brib'd speaks, makes itself to be heard, uses Reproaches, agitates the Soul, fills it with Disquietudes, with salutary Terrors. Can the Infidel, even in this so constant Remorse, hinder himself from observing

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serving the Voice of God himself whom he is afraid of acknowledging, and who calls back the Ingrate flying from him.

How long, O Lord, wilt thou suffer Ingratitude, in spite of the Cries of Conscience and Reason, to abuse thy Light, and thy Benefits, in endeavouring to annihilate thyself? Humble those presumptuous, unpeaceable Spirits, which rebel against the supreme Sovereign; *Fill their faces with shame.* Strike; and those who do not acknowledge thy beneficent Hand, shall feel the weight of thy Arm, falling heavy upon their heads. Finding no more Refuge in Vanity, in trifling Friends, in the Favours of Fortune, they will turn their Eyes toward thee, *And will seek thy Name^c.* Or rather make those pleasant, but lively and effectual Rays, to shine into the innermost recesses of their Souls, which have so often triumphed over the Ungodly. And the Unbeliever joining at last his Voice with that of all wise and judicious Men, will glory to bless and adore with Submission the mighty Hand which called both the Heavens and the Earth out of Nothing: *And they shall worship before thee, O Lord^d.*

^c Psalm lxxxii.

^d Psalm lxxxv.

The End of the Third Volume.